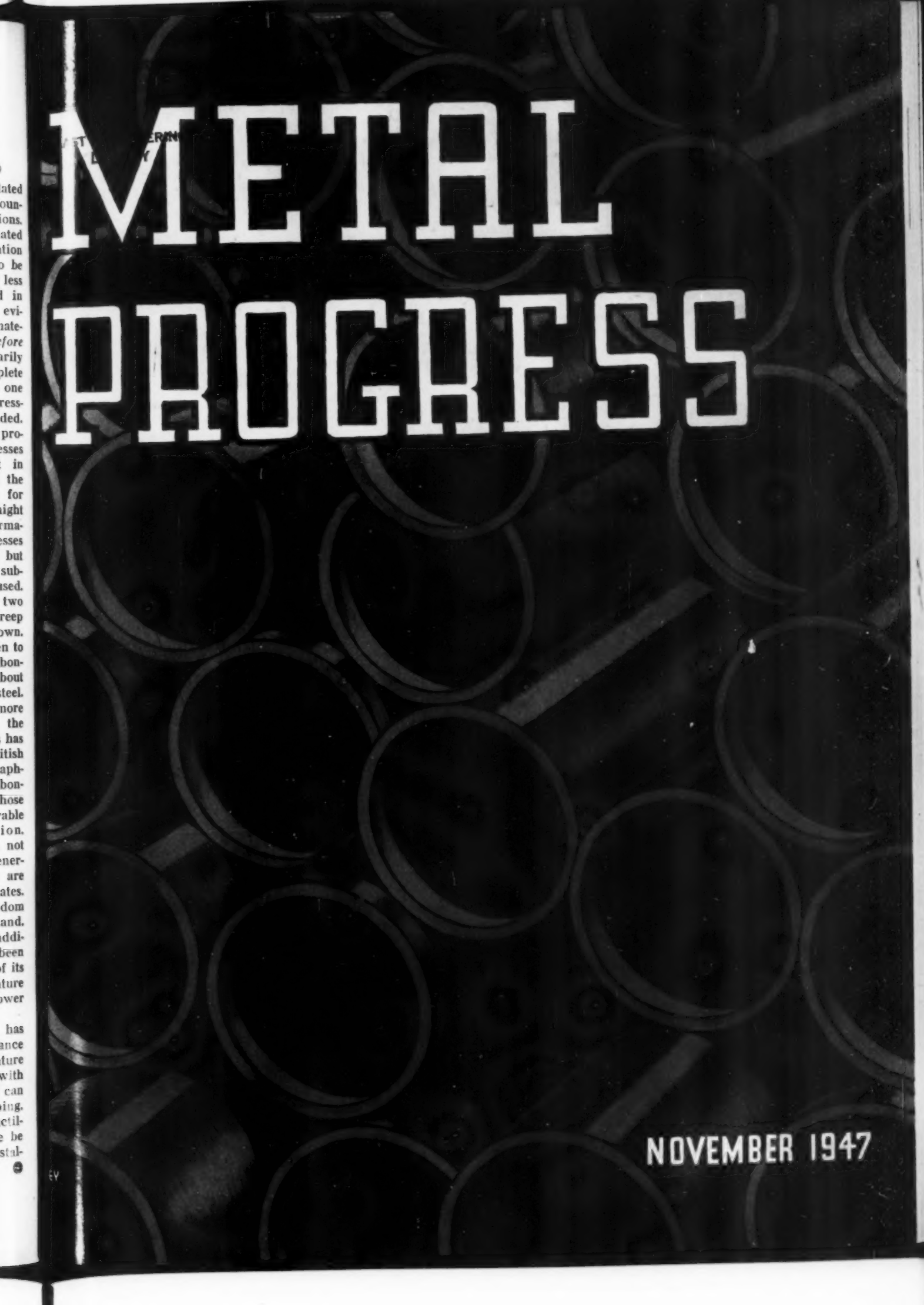
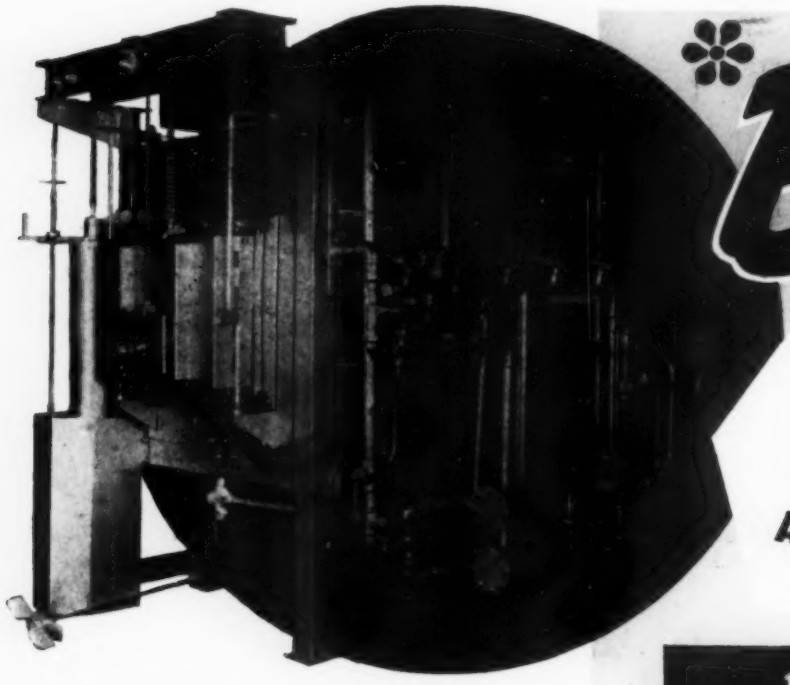
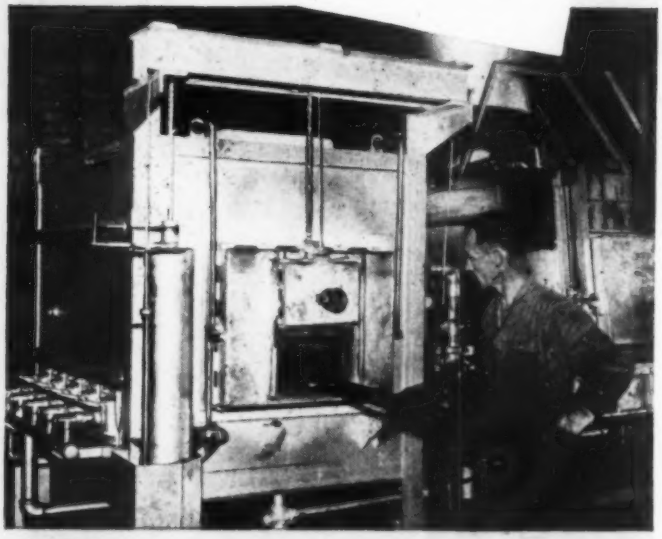

METAL
PROGRESS
NOVEMBER 1947



Balco

The New CONTROLLED-CARBON ATMOSPHERE FURNACE



MOST OPERATIONS LEAST INVESTMENT

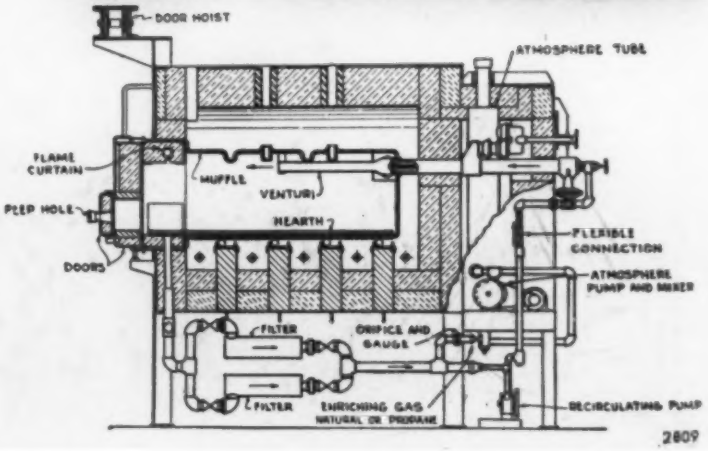
The new Balco Furnaces provide clean, scale-free hardening, gas carburizing, and carbon restoration of plain and alloy steels. This is accomplished by the accurate control of the carbon potential of the atmosphere.

The Balco Furnace is a **Standard-Rated, Gas-Fired, Atmosphere Furnace of the muffle type with an integral RX atmosphere generator, and is available in three types—two for clean hardening and one for gas carburizing. Of the former, one type has a temperature range from 2000° to 2400° F, the other from 1400° to 1850° F. The range of the gas carburizing furnace is from 1400° to 1850° F.

The Balco Furnaces make available to the small furnace user a multiple-purpose unit for clean hardening, gas carburizing, carbon restoration, and other carbon controlled heat treatments. One such Balco unit in operation in a large commercial heat treating plant has successfully processed 67 different grades of tool steel.

* BALANCED $\frac{CO}{CO_2}$

Write for full details and performance figures.



** Every 'Surface' Standard Furnace is rated so that you can tell in advance the exact production, fuel consumption, and all other operating data. This is an exclusive feature that no other furnaces have.

'Surface'

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

Metal Progress

November 1947
Vol. 52, No. 5

Table of Contents

The Atomic Age

The Metallurgist and Atomic Energy .. 800
by Robert F. Bacher

Technical Articles

Ductility of Steels for Welded Structures .. 795
by A. B. Kinzel

Caustic Cracking of Welded Steel Plate .. 803
by H. M. Wilten

Effects of Germination in C-Alloy Magnesium Castings 806
by John McCabe and W. H. Sharp

The Heat and Mass Flow Analyzer — a Tool for Heat Research 813
by Victor Paschkis

Protective Metal Coatings From Molten Salts 819
by Harry R. Hoge

A Systematic Scheme for Identifying Corrosion Resistant Metals 824
by Chester J. Zeeh

Maintenance of Metallic Trim at Rockefeller Center 833
by Myron Weiss

Bits and Pieces

Preparation of Alumina Abrasive 809
by Harry Stern and Paul R. Totten

Logarithmic Scales of Odd Lengths 810

Chips for Chemical Analysis 811
by C. O. Lundberg

A Temporary Holder for Polishing Metal Specimens 811
by Henry Leidheiser, Jr.

Selective Annealing of Nonferrous Metals .. 812
by L. H. Seabright

Correspondence and Foreign Notes

Can Hardenability Bands Be Narrower? .. 825
by L. W. Cashdollar

Low-Nitrogen Steel (a Correction) 826

A Measure of Dispersion of Carbide Spheroids 827
by N. T. Belaiew

Mathematical Analyses of Metallurgical Data 828
by Michael G. Corson

Coalescing Anneals 829
by Albert M. Portevin

Width of Crack Discoverable by Deep Etching 830
by Russell H. Lauderdale

Tiger, Tiger, Rah, Rah, Rah! (a Ghost) .. 831
by Mrs. I. M. Poppe

Sponsored Research in Britain 831
by Tom Bishop

Creep in Hot Valve Springs 832
by Alberto Oreffice

Abstracts of Important Articles

Alumina From Clay 846
Abstract of note from National Bureau of Standards

Carbon Brick 854
Abstracted from "Progress Report on Carbon Linings for Blast Furnaces", by V. J. Nolan, *Blast Furnace and Steel Plant*, April 1947, p. 454 to 460.

Crack Sensitivity 856
Abstracted from "Improving the Weldability of High Strength, Low Alloy Steels. Part III", by S. L. Hoyt, C. E. Sims and H. M. Banta, *Iron Age*, June 14, 1945, p. 74 to 80, 148.

Departments

Data Sheet: Identification of Corrosion Resistant Metals 824-B
by Chester J. Zeeh

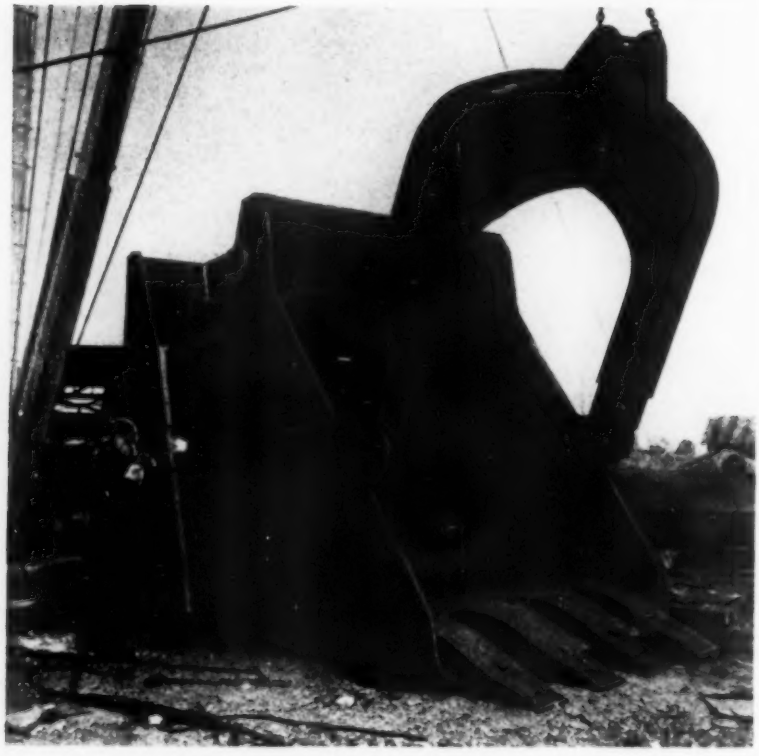
Personals 836, 838, 840, 842, 844

Manufacturers' Literature 848-A, 848-B

Advertising Index 896

Copyright, 1947, by
THE AMERICAN SOCIETY FOR METALS
The Society is not responsible for statements or opinions printed in this publication

This Bucket holds 77% MORE ..yet WEIGHS 23% LESS



This stripper bucket is another example of how large weight reductions can be made with Hi-Steel. Yet it welds as well or better than ordinary structural steel, and it can be cold formed, hot worked, and machined just as easily, so that the most economical fabrication processes can be used.

when made of INLAND HI-STEEL

The capacity of this stripper bucket was increased 77% while its weight was reduced 23% by the use of low-alloy, high-strength, Inland Hi-Steel. The bucket was originally made of cast metal and weighed 47,000 lb. Its capacity was 13 cubic yards. By designing to take advantage of the great strength of Hi-Steel, the weight of the bucket was reduced 11,000 lb and its capacity increased to 23 cubic yards.

Inland Hi-Steel has nearly twice the working strength of ordinary structural steel, 50% greater ability to stand up under impact loads, and a marked resistance to vibration. In addition, it has about five times the atmospheric corrosion resistance and is far more resistant to abrasion.

Unfortunately, the present demand for Hi-Steel continues to exceed the supply. To make larger tonnages available to you, other steel companies have been licensed to make this superior product. Write for Engineering Bulletin No. 11, INLAND STEEL CO., 38 S. Dearborn St., Chicago 3, Ill. Offices in: Detroit, Indianapolis, Kansas City, Milwaukee, New York, St. Louis, St. Paul.

INLAND HI-STEEL meets the requirements of SAE Specification 950

INLAND STEEL

AVERAGE PROPERTIES OF INLAND HI-STEEL compared with those of ordinary structural steel

	INLAND HI-STEEL	ORDINARY STRUCTURAL STEEL
TENSILE PROPERTIES (¼" Plate)		
Yield Point	62,000 lb per sq in.	33,000 lb per sq in.
Ultimate Strength	74,000 lb per sq in.	66,000 lb per sq in.
% Elongation in 8 in.	24%	25%
ENDURANCE LIMIT		
Fatigue Strength	49,000 lb per sq in.	33,000 lb per sq in.
IMPACT RESISTANCE (Charpy Impact in Ft Lb)		
Temperature		
80 degrees F	55.3 ft lb	36 ft lb
32 degrees F	43.1 ft lb	33 ft lb
15 degrees F	39.5 ft lb	29 ft lb
0 degrees F	36.3 ft lb	26 ft lb
—10 degrees F	36.8 ft lb	16 ft lb
—25 degrees F	33.7 ft lb	6 ft lb
—50 degrees F	30.4 ft lb	2 ft lb
PHYSICAL PROPERTIES FOR RIVET DESIGN		
Shear Strength	66,000 lb per sq in.	44,000 lb per sq in.
Bearing Strength	115,000 lb per sq in.	95,000 lb per sq in.

Ductility of Steels for Welded Structures

Abstract of Campbell Memorial Lecture

By A. B. Kinzel
Vice-Pres., Electro Metallurgical Co.
and Union Carbide and Carbon Research Labs.
New York City

Most of what follows is literally copied from the lecture's text — a plan that is followed with the more assurance since the lecturer presented his subject extemporarily in the most fluent and interesting manner possible. Obviously either method gives only an outline of the entire subject, argued skillfully at length by the author and supported by a great mass of test data. The complete document will appear in the next volume of ⊕ Transactions, *to be printed early in 1948.*

THE DIFFICULTIES of dealing with any subject in which most of the "facts" are fraught with uncertainty are obvious. Such is the case in the field of ductility of steels for welded structures. Investigators have recognized that ductility is the essence of weldability, yet "weldability" has never been satisfactorily defined. The difficulty lies in that it is so all-embracing. So for our purposes let us agree that a steel is weldable if the weldment will have properties not too different from the unwelded steel. If so, which of these engineering properties are critical with respect to the intended service?

Broadly, these are of two groups: *(a) Strength,* which includes many items such as proportional limit, yield, ultimate and fatigue strength, and *(b) ductility,* which includes elongation and reduction of area during fracture, notch sensitivity, impact strength, plain and notch-bend performance, and the concept of transition temperature. Strength can be measured directly and the figures are used by the designer. Ductility is arbitrarily set on the basis of experience, as it is the predominant factor under abnormal conditions.

I submit, therefore, that the essence of the weldability problem is ductility of the weldment.

The conventional criterion of ductility has been elongation and reduction of area in the static tensile test. Minimum values were set, based on experience with bolted or riveted structures, where minor slippage at the joints can take place. With welded structures, a new situation arises. The structure can adjust its shape only by plastic flow of the material. Moreover, a failure in a local section can propagate throughout the whole structure. Unless there is plastic flow in a structure to relieve concentrated stresses, the entire elastic energy of the loaded structure can be relieved only by a crack, and when such a crack starts, the material at its end is subjected to the force corresponding to the release of this energy. Failure without plastic deformation has an extremely low time factor, so that the *force* is of a very high order.

This brings us to the crux of the matter. *All* steels will show plastic deformation before failure under some service conditions. Under other combinations of rate of loading, restraint, stress distribution and temperature, all steels will show *absence* of plastic distribution before failure — that is, show brittleness.

Let us now consider the combinations of factors, discoverable by laboratory testing, that

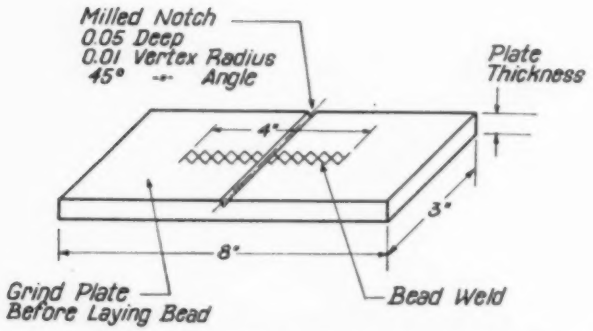


Fig. 1 — Slow Bend Test Plate, Bead Welded; to Be Tested in Bending, Notch in Tension. Bead weld is made with automatic equipment, direct current, reversed polarity, 175 amperes, 26 volts, at 6 in. per min. with $\frac{3}{16}$-in. E6010 electrode

correspond to the important conditions of service. In engineering structures, be they bridges, ships, or tank cars, the rate of loading under normal service is of the same order as in "static" testing. Degree of restraint and stress concentration is rarely much worse than that comprised in a test specimen with a standard V-notch. Temperature of service may be as low as —40° F. It would appear that a steel could be appraised for welded structures by testing it under similar combinations.

An enormous amount of study has been given to the effect of hardening next to the weld as a result of the heat treatment incident to the welding operation.* While these studies have clarified thought in this field, they deal with only one factor in loss of ductility — that is, hardness.

The T-bend test (a double fillet T-shaped specimen, tested — as welded — as a guided bend specimen) was an advance in that it required consideration of the *mode* of failure — that is, whether ductile or brittle. Early investigators using the T-bend test showed that the temperature of testing had an important effect on the angle of bend and mode of failure. The T-bend test is primarily applicable to low hardenability steels, such as used in ship construction, and integrates the performance of a welded joint, the quality of base metal, and the effect of welding. It does not compare base metal and welded specimens.

Others have studied notched specimens, welded and unwelded, under slow bending. Slow bend of a plate with longitudinal bead is useful, especially if there is a notch cut across the weld bead in order to restrict the deformation to a small portion of the weld test specimen; then it becomes reasonably satisfactory for study of structural steels over a wide range of welding conditions.

*See "Guide to Weldability of Steels", published by the American Welding Society, 1943. For a summary of the studies, see *Metal Progress* for February 1944, page 298.

There has also been a general trend in weldability testing to use low temperatures as a determining variable, and to recognize that service performance of a steel or weldment is related to its transition temperature.

Principles of Test

Broadly, all the factors which reduce ductility should be integrated in the test piece in a manner analogous to their integration in service behavior. Obviously, the specimen should involve actual welding. If its thickness should be the same as the thickness of plate intended for welding, the mass effect is automatically matched. By using a

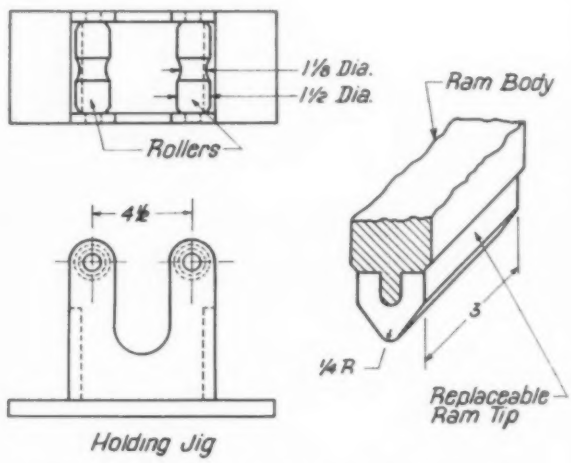


Fig. 2 — Jig for Slow Bend Test. For use at subatmospheric temperatures only the ram tip needs to be refrigerated

specimen with longitudinal bead and sufficient width so that welding heat does not raise the far edges above 200° F., we include all zones of interest with respect to heat treatment. By notching the specimen at right angles to the weld, each of the zones is notched. If this specimen (Fig. 1)† be then tested in static loading as a beam simply loaded in the plane of the notch, as in the jig shown in Fig. 2, we have a specimen comprising all notch-sensitive areas in the weldment and in which failure will be initiated by the most notch-

†The test specimen was chosen after studying 11 designs, wherein the bead was either longitudinal or transverse, and the specimen width and the notch dimension varied. Such studies were made of four commercial high-strength structural steels. Temperatures were varied, down to —110° F. Angle of bend at first crack was recorded. Reproducibility of results, good indication of transition temperature, consistent reflection of imposed welding variables — such were the criteria that resulted in the selection of the preferred test piece.

sensitive area. (Probably a single temperature of test could be established — after research — with the proviso that failure must then be of ductile character.) The 45° V-notch with 0.01-in. bottom radius, 0.05 in. deep, in a 3-in. wide specimen represents about the worst probable stress distribution in an engineering structure. Likewise, the rate of loading corresponding to the 1 in. per min. motion of the ram in testing is of the same order of magnitude as the rate of application of loading stresses for structures in "static" service. In the specimen, the only dimensions which must be accurate pertain to the notch. It is indexed from the surface of the plate, cut with an accurate fly cutter or milling cutter.

Much study was given to a precise criterion of embrittlement. Energy absorption, angle of bend, ratio of areas of crystalline-appearing to fibrous-appearing fractures, and ratio of load at proportional limit to maximum load were all examined and found wanting. It was at this point that we once again resorted to reasoning from service failures, which always show glaring crystalline facets in the fracture, invariably at the origin. However, when the crack has not gone through the entire structure, some fibrous areas always appear at the edges near the end of the fracture, and whenever this occurs there is a small but definite (on the order of 1%) reduction in cross section of the plate material.

Accordingly, the width of the specimen adjacent to the notch is measured with a micrometer caliper, and compared with the width $\frac{1}{32}$ in. below the notch. The proportionate difference is the "lateral contraction". Under the established test conditions, a measured contraction of 1% (which, as just pointed out, corresponds to the deformation measured in service failures at the section near the end of cracks which stop propagating) will mark the temperature of test as the "embrittling" temperature.

For tests at subatmospheric temperatures, the test piece and ram tip are immersed in appropriate mixtures of acetone and dry ice to give temperatures down to −110° F.; from −110° F. to −240° F. a bath of petroleum ether circulating through a heat exchanger cooled by liquid nitrogen will be a useful refrigerant.

From a practical standpoint, it is worthy of note that it is possible to prepare and test such a "platform" specimen directly from a steel heat in less than 4 hr. from teeming to final result.

Summary of Test Results

Having chosen the test piece and method, and a quantitative index for ductility, the next step was to test a wide variety of steels in various states and determine whether the results generally were to be expected, and from the data to attempt to explain steel behavior. Fifteen commercial steel heats were secured (five plain carbon, six low-alloy structural, and four engineering alloy steels) and nine experimental* steel heats made (three plain carbon and six alloy). The complete study includes thousands of test results, which are summarized in 20 diagrams.

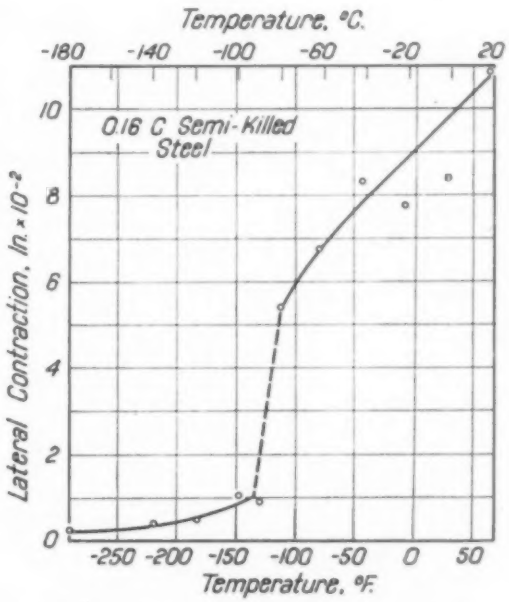


Fig. 3 — Typical Transition From Ductile to Brittle Temperature at −110 to −130° F. (−80 to −90° C.) in 0.16% Carbon, Semikilled Steel

A glance at these tables or charts shows that all of the steels exhibit ductile behavior at some testing condition, and brittle behavior at some other testing condition — *temperature* being the main variable with which we are concerned in this study. Lowering of ductility with lowering of temperature is in no instance a proportional relationship. In some of the steels the lowering of ductility with temperature is gradual over a wide range of temperature. In many others, slight lowering of ductility occurs as the temperature is lowered until some rather narrow critical range of temperature is reached when the loss of ductility is extremely rapid with lowering temperature. A typical case is set forth in the data of Fig. 3.

Results of tests wherein other factors than temperature were varied showed (as expected by

*The lecturer described the melting and refining methods for these 100-lb. induction furnace heats in some detail, since he believes that the routine has a major effect in lowering the transition temperature, ductile to brittle fracture, in comparison with commercial basic openhearth heats of the same analysis.

theory) that higher velocity of testing and greater degree of restraint act in the same direction as lowering the temperature of test — that is, in increasing the proportion of the fracture which exhibits a brittle, coarse crystalline appearance.

One of the findings of these comprehensive tests of most interest to designers, therefore, is that the deleterious effect of restraint in the structure has not been overemphasized in recent literature. In this regard the welding engineer also has great responsibility to specify the proper cycle of operations to minimize the restraint imposed by the differential heat effects of the welding operation, and to insist on proper preliminary heat treatment (normalizing) or post heat treatment

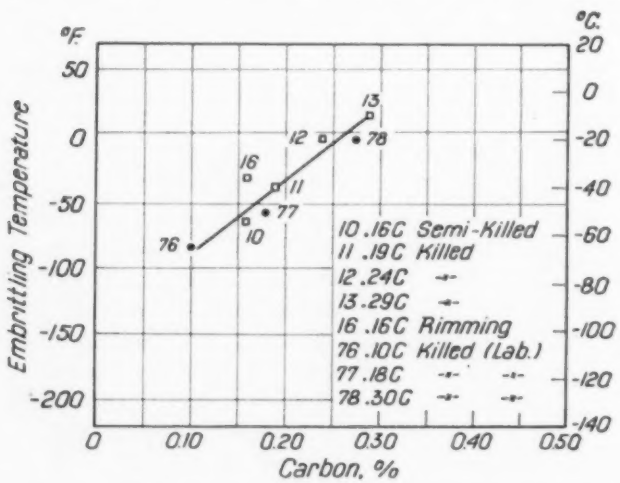


Fig. 4 — Effect of Carbon on Embrittling Temperature; ½-In. Plate, Normalized and Welded

(stress relieving anneal) when their additional necessity is indicated.

The type and analysis of the steel and its metallurgical condition are also of very great importance. The essential, of course, is the ability to deform plastically under severe conditions. Of these factors the following are of most importance — deoxidation practice, chemical composition, metallographic condition.

As to deoxidation practice, we have never been able to determine that factor in laboratory induction heats which improves their character over commercial heats, either electric or openhearth. The procedure differs radically, but we have never found any correlative difference in chemistry, gas content, grain size or microstructure. Suffice it to say now that this is a question of importance to be solved by the metallurgical engineers.

That the nature of the steel, chemical or otherwise (but independent of heat treatment and the state of rolling or strain), has a marked effect on the embrittling temperature is obvious from the results. Carbon plays a dominant role — it is the most important single factor in determining the level of the embrittling temperature. This is illustrated in Fig. 4, and the conclusion is further substantiated by results for the alloy steels. That alloys, as such, have a major effect in lowering the embrittling temperature for a given strength level is also evident, although conclusions respecting the effect of individual alloys or alloy combinations cannot be drawn. It is certain that alloy steels after welding show a higher resistance to conditions that produce embrittlement.

Finally, the metallographic condition is likewise an important factor for a steel of any given nominal analysis. Normalizing (which lowers the internal locked-up stresses) naturally renders the material ductile at lower temperatures than in the as-rolled condition.* While much work by many investigators has shown the important effect of grain size and of hardness, the present investigation admits of no quantitative correlation, although the general trend is evident. The quench effect of welding heat is readily apparent from our data; the more severe the heat treatment from the standpoint of quench effect and the wider the zone under the bead which is so affected (that is, the greater the heat input during welding), the higher the temperature where brittle behavior occurs.

It has also been well demonstrated that the embrittling temperature for steels which have been through-quenched and tempered is appreciably lower than for companion samples in the normalized or pearlitic state. Also that straining raises the temperature; this is not strange, as total plastic deformation is not unlimited, and prior straining uses some of it. The effect of a small amount of prior strain is of major consequence only in the less ductile, high-carbon steels.

Criterion of Service Performance

Consider, then, how the test would be applied by engineers and manufacturers when welding is involved. The general specification would describe the test piece (Fig. 1), the testing jig (Fig. 2), and

*The lecturer, in his extemporary presentation, interpolated some remarks to the effect that plate material shows a difference of behavior in most tests if the direction of major stress is changed from longitudinal to transverse to direction of principal extension in rolling. In the present tests it is also true of high deformations, but it is not true at 1% contraction. Since 1% contraction stops the crack, there is *no* difference in behavior of plate with respect to rolling direction in this critical matter. This conclusion is amply supported by observations of the direction of cracking in structures which have failed: the cracks have a fine disregard of rolling direction.

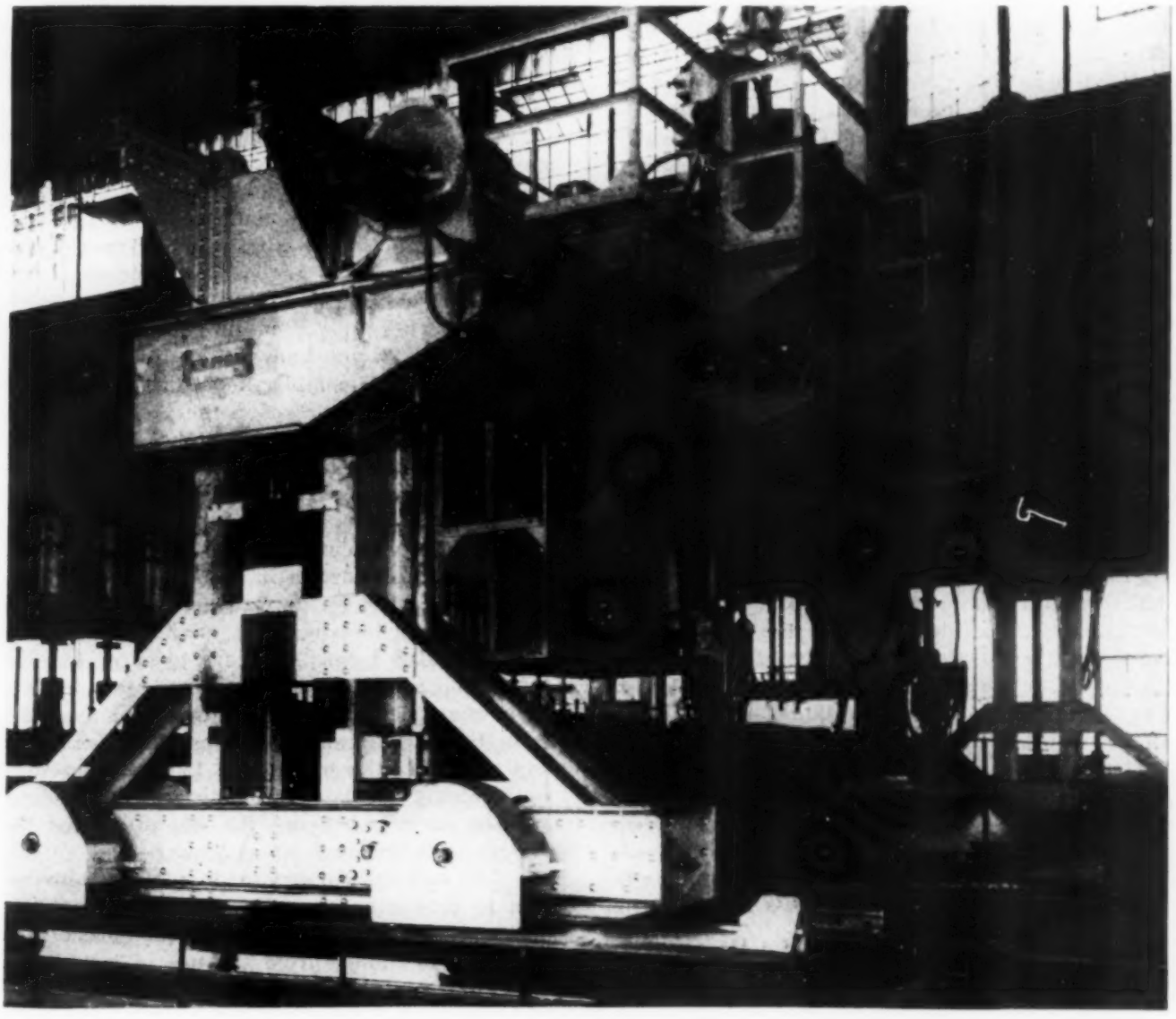
the details of test procedure. Only one test temperature need be used. At the given temperature the fracture should have enough ductility so that more than 1% lateral contraction can be measured. It would be a "go, no-go" test to the extent that the metal would not be used if the embrittling temperature proved to be higher than the specified test temperature.

This test temperature is a matter of engineering judgment, and should be related to the intended service. For structures intended for indoor service without refrigerated contents, and for tankage buried outdoors, 0° F. (−20° C.) appears to be consistent with other criteria applied in the past, as well as general engineering experience. This same temperature could well be set for marine structures in which the material does not reach temperatures appreciably below 0° F.

For general outdoor service in the United States, −40° F. (−40° C.) appears to be a test temperature which would insure safe performance without undue penalty. If structures are used in low temperature service, as in the chemical industry, testing at 20° F. (10° C.) lower than the lowest expected temperature is suggested.

Specimen performance should be minimum 1% lateral contraction, but ductility in itself is no more than a factor of safety; even if it be low, it does not mean that failure will occur. The test conditions provide an analogue to normal design, but the designer can do much to increase the ductility of the structure as a whole.

Automatic Welders for Structural, Ship and Tank Steel Sometimes Come Pretty Big! Two Unionmelt welding heads on gantry take current of 4000 amperes and ½-in. weld rod



The Metallurgist and Atomic Energy*

By Robert F. Bacher
Commissioner, U. S. Atomic Energy Commission
Washington, D. C.

IN TALKING about the metallurgist and atomic energy, I am reminded of an experience which General McNaughton had some years ago. General McNaughton is the Canadian representative on the United Nations Atomic Energy Commission and also the head of the Canadian atomic energy project. Some years ago he became president of the National Research Council of Canada. When he started that work, his first and most pressing task was to discover new uses for the uranium which had been accumulated in the production of radium.

That little problem seems to have been taken care of!

The development of atomic energy has a very close relation to metallurgy and metallurgists. On the one side, some of the products of the atomic energy program are proving themselves invaluable tools in the prospecting of new metallurgical methods and in the discovery and perfecting of new materials. On the other side, the development of atomic energy itself cannot be carried to anything like the degree of perfection which one can now envision without the very greatest aid and help from metallurgists in the development of new materials.

Metallurgy is not only an interesting subject, but it is, and always has been, a subject of immediate, practical applications. Its development goes back in ancient times to our earliest recorded history. Its progress throughout these ages has very greatly affected our civilization. During much of this time, metallurgy has been, perhaps, more an art than a science. At any rate, we should probably regard it as an intermingling of art and science. Some of the significant developments have been directly traceable to intuition — to hunches, if you will — by brilliant men who observed a queer phenomenon as a result of one of their experiments or trials.

*Address before the annual banquet, American Society for Metals, Chicago, October 23, 1947.

The realization of atomic energy and the development of the atomic bomb would not have been possible without the metallurgist. Your contribution was a vital one.

Probably the most spectacular contribution was the work on plutonium. Here was a metal, not existing in nature, which was finally produced in quantity from uranium in the massive nuclear reactions at Hanford on the Columbia River. It was a long time before enough of this material existed so that its bulk properties as a solid could be determined.

The metallurgy of plutonium was entirely new. Experiments had to be carried out under the most difficult and trying conditions, since the material itself is highly radioactive. There was never very much of it with which to work, and the greatest ingenuity and perseverance were necessary. In addition, it turned out that the solid-state properties of plutonium were unusually complicated. As you know, these difficulties were overcome and the complications unraveled by the metallurgists who worked on the problem. They were aided, of course, by the other members of the unusual scientific and technical team which worked on the whole atomic energy project. It was an extraordinary achievement in metallurgy!

Another problem which was solved during the war was the production in quantity of pure uranium metal. Before the war, uranium metal had been produced in only small quantities and in a highly divided form. In order to carry out the production of plutonium, it was necessary to have large quantities of pure uranium metal in solid form. It was a big job, but the problem was solved and the difficulties overcome. Laboratory results were quickly translated into large-scale production, and the barriers between the laboratory and the factory were broken down as never before.

The metallurgist has made a great contribution to atomic energy. Now, at present, atomic energy is beginning to help the metallurgist. The first help is coming from the use of isotopes as tracers. I venture the prediction that tracers will

prove to be invaluable tools both in the understanding of the solid state of matter and in the solution of practical problems in metallurgy. The number and variety of applications of tracer isotopes are already impressive.

As you know, it is possible to produce atoms, or isotopes, having all of the chemical and metallurgical properties of normally stable atoms but whose atomic nuclei are unstable — in other words, radioactive. These unstable nuclei disintegrate with the emission of radiation which it is possible to detect and follow. Ordinarily it would be very difficult to follow the course of particular atoms through complicated chemical reactions and involved metallurgical treatments. The use of tracer isotopes offers a simple way to follow the progress of atoms.

In the nuclear reactions which have been developed for the production of fissionable material, we are today producing radioactive isotopes of common elements on a scale never before available. Tracer isotopes in quantity are here *today;* their production does not depend upon some future development.

Radioisotopes are telling us, for example, what happens to the metal on high-speed ball bearings. They tell us how fast it wears off and where it goes, even though the amount of scruff is so minute it could not otherwise be detected.

Again, in producing iron, incidental sulphur must be carefully removed. Radioactive iron and sulphur today are being used to determine the distribution of sulphur between slag and metal.

You are familiar with the major changes in the properties of a metal which can be achieved with very small amounts of other materials. Tracer isotopes will probably help us to understand why such changes occur. With such understanding, the metallurgist may learn how to make new alloys with properties superior to those we know today.

The same could be said for the use of tracer isotopes in the study of crystal changes, of heat treatment, and of cold working. We are only beginning to realize the number of ways in which radioactive isotopes can be used to learn more about matter in the solid state.

Tracer isotopes of another type are also being produced now. During the war, as a part of the atomic energy program, it was necessary to separate uranium atoms of mass 235 from those of mass 238 on a tremendous scale. This separation was necessary because only the uranium of mass 235 is fissionable with low-energy neutrons, or (in other words) has the rare property of nuclear inflammability. Several methods were developed to separate the uranium isotopes, and these methods are now being employed to separate the stable isotopes of other elements.

At the present time, stable isotopes of various elements — iron, nickel, copper, and many others — are being separated in small quantities at Oak Ridge. These stable isotopes can also be used as tracers, since they can be detected with great sensitivity by a mass spectrograph. This sounds like a complicated piece of equipment, but it is widely used today in the oil industry and will, doubtless, be used for many other applications.

The use of stable isotopes will greatly supplement the use of radioactive isotopes. Several elements do not have radioactive isotopes with convenient lives. Others may have so many radioactive isotopes in a normally prepared sample that it may prove advantageous to produce radioactive isotopes from the separated stable ones.

A more complete understanding of metals and of the solid state is gradually being achieved, and the use of tracer isotopes is helping. During the past 25 years, the advance in our knowledge of atomic and molecular physics has been very great. We have come to have some knowledge of complex atomic phenomena which we understood not at all before. It happens that the study of solids is one of the most difficult fields, because we need to have an understanding not only of the atom, or even of the molecule, but we need to know how atoms and molecules act together under the conditions in which they find themselves in a solid.

You might say that this requires a degree of understanding of atomic science which goes far beyond that necessary to explain the simple phenomena of individual atoms and molecules. We are just coming into this age of fuller understanding. We have, today, a little better understanding of some of the peculiar properties of crystals, some of the ways in which small amounts of material may greatly affect the structures of solids, and, indeed, some of the conditions which go to make one material a conducting metal and another an electrical nonconductor. The rate of progress in this direction is growing, and I feel that we can look forward to an ever-increasing understanding of some of these complex phenomena. The use of tracer isotopes will certainly play a major role in the solution of these problems.

While the metallurgist has played a vital role in the development of atomic energy, the job is just well started. Looking forward, it is possible to see that the accomplishments of the war are but the prelude to those which will be necessary for the long-range development of nuclear reactors. The present ones, which produce plutonium from uranium, subject the structural materials of the reactors to most unusual conditions. In addition

to the very high rate of heat generation from the process of fission, all of the materials comprising the interior of the reactor are subjected to the most violent radiation from the fission process. These radiations may change the physical properties of the materials quite considerably.

It may turn out that the physical changes produced in nuclear reactors will lead to the use of reactors for the production of materials with properties not otherwise obtainable. Treatment in a nuclear reactor may become a procedure for production of special metals and other materials. It is too early, however, to consider such a suggestion as more than speculation.

But this is only the start. Up to the present, we have worked with reactors in which the demands upon the structural materials have been relatively small compared to what we foresee for the future. For example, the present nuclear reactors operate at relatively low temperature. Furthermore, the intensity of the radiations to which the materials are subjected, while high by ordinary standards, is relatively low compared to that to which future materials will be subjected.

The successful development of reactors which can be used for the production of electrical power from the atomic nucleus depends upon the development of equipment for working at higher temperatures. It is true, of course, that electrical power could, as a demonstration, be produced from the low-temperature reactors which now exist, but this would not be the basis for a practical development. In order to obtain a high efficiency in the conversion, it is essential that higher-temperature reactors be devised and built.

Now, such a development looks quite possible at the present time. The future looks quite promising, but there are a great many difficulties to be overcome. When one starts to search for a material which will be usable in a nuclear reactor, he must, first of all, look to its nuclear properties. Unlike the specifications for most of the other uses to which metals are put, when used in a nuclear reactor the fundamental nuclear properties are vital. If the nuclear properties of a material are unfavorable, all other favorable qualities are of no use. The nuclei of some atoms have an absorbing power for the neutrons, with which the nuclear reactor is flooded, a million times greater than the nuclei of other atoms. The tremendous effect of a trace of impurity becomes immediately apparent, if it be atoms of such an absorber.

In the construction of the first reactors, almost every other quality had to be sacrificed in order to make the reactor work. For the future development, these conditions may be not quite so stringent. There is now the possibility of using purified fissionable material. The construction of a reactor with such purified fissionable material is very much easier, and the amount of neutron absorbing material which may be used in the reactor is somewhat greater. It is true, of course, that the use of too much absorbing material may make the reactor inefficient, so that this limitation still is with us. But the number of possibilities will be increased for the future reactors.

The requirements put upon the materials will ever be greater. The development of suitable materials which will stand up to the conditions to which they are subjected at high temperature has barely begun. Still much higher temperature than that needed in reactors for the production of electrical power will be demanded if atomic energy is ever to drive an airplane. Such a development will not be successful without the aid of metallurgists. The very greatest ingenuity will be necessary.

The nuclear requirements may be such that it will be necessary to prepare separated isotopes for these materials in sufficient quantities that they may be used as vital constituents in the structure of certain reactors. At the present time, the whole subject of reactor development and the detailed knowledge of the nuclear properties of the various materials is insufficiently well determined to tell whether such a course will be necessary. It will greatly simplify the problem if it is not. Only by the very closest cooperation and collaboration between those who are skilled in the development of new materials and those who are concerned with the nuclear aspects of reactors will these questions be answered.

It is not only for the production of electrical power that the development of nuclear reactors is needed. These nuclear reactors produce fissionable material. This fissionable material is the vital substance either as nuclear fuel to be burned in other reactors, or as the vital component of the atomic bomb. In either case, it is the fissionable material which is the key. Production of this material, as well as the production of power and nuclear engines, is closely tied to the development of nuclear reactors which will be tremendously better than those now in operation.

The development and further exploitation of atomic energy — whether it be for peacetime developments, or whether it be in the production of weapons — is intimately tied to the development of materials with properties which we have never seen before. In this work, metallurgists must play a leading role if the development is to be successful. Here is a new field opening before you, which is vital to the well-being of our country.

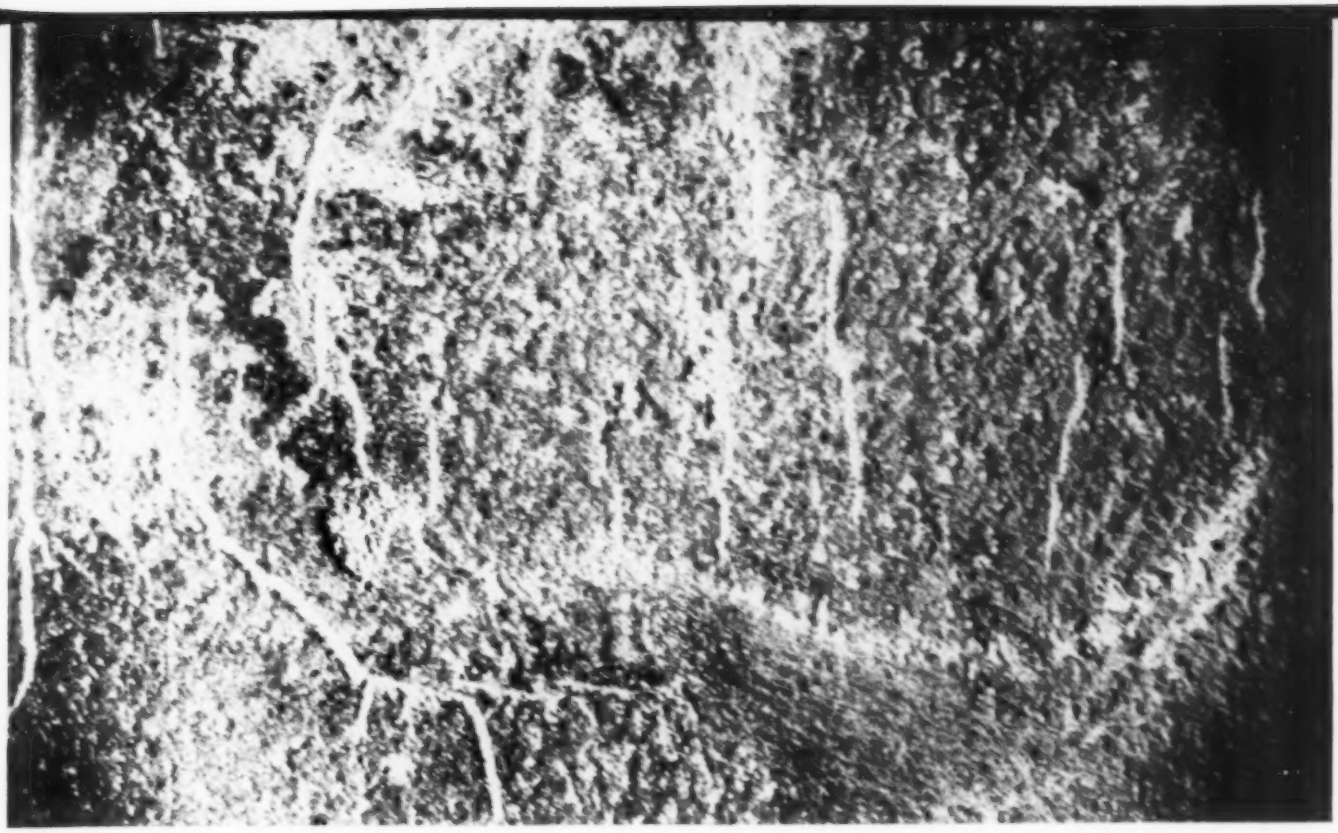


Fig. 1 — Cracks on the Inside Surface of the Shell of the Reboiler, as Indicated by Magnaflux Inspection; 1½ Size

Caustic Cracking of Welded Steel Plate

By H. M. Wilten
Metallurgical Dept.
The Texas Co.
Port Arthur, Texas

CAUSTIC CRACKING of riveted steel plate is by no means a rare phenomenon. It has been made a subject of many metallurgical papers. On the other hand, failure of *welded* steel plate from caustic cracking is apparently very rare since no such failures have been described in the literature. For this reason it was thought that data about such a failure would be of interest. This failure occurred in a shell of the reboiler in one of the units of the refinery of The Texas Co. at Port Arthur, Texas.

The reboiler, which is in effect a heat exchanger, had steam inside the tubes and light hydrocarbons in the shell at inlet temperature of 358° F. and at 100-psi. gage pressure. The shell plate was specified to be of firebox quality steel, conforming to A.S.T.M. specification A70 with 0.30% carbon max. End flanges were specified to be made of forged steel, A.S.T.M. specification A181, Grade I with 0.30% carbon max. (special limitation for weldability). It is to be noted that both of the above specifications limited the steel's carbon content. The welded construction was in accordance with the A.P.I.-A.S.M.E. Code for Unfired Pressure Vessels. No stress relieving was required after welding. The shell was designed for 150-psi. pressure and maximum temperature of 400° F.

The bottom shell of the reboiler close to the

cover flange was found leaking during operation. The reboiler was shut down, steamed, cleaned and sandblasted; the inside of the shell was then completely inspected by magnaflux. This examination revealed numerous cracks partly through, and on each side of, the weld connecting the shell to the end flange. The total failed area was approximately 15 in. wide by 48 in. long, the latter dimension being in the circumferential direction. Figure 1, at the head of the article, illustrates (at 50% enlargement) magnaflux powder ridging over

Fig. 2 — Cracks on the Inside Surface of the Shell of the Reboiler, Etched in Fry Reagent. 1½ ×

cracks on the inside surface of a portion of the cracked area.

Another piece of the cracked portion of the reboiler was etched in Fry solution (cupric chloride, hydrochloric acid and water). Figure 2, magnified 1½ times, illustrates the results. The right side of the photograph shows cracks in the shell plate which extended into the weld itself; the left edge of the photograph is of the cracked hub of the end flange, and again some of the cracks extend into the weld proper.

The chemical analysis of the principal constituents of this structure is as follows:

	Carbon	Sulphur	Phosphorus
Flange	0.34%	0.023%	<0.040%
Specified	0.30	<0.05	<0.05
Shell	0.16	0.027	<0.040
Specified	0.30	<0.04	<0.035

Note that the carbon content of the flange was higher than that specified in the order. Physical tests on two specimens selected from the steel plate adjacent to the cracked area resulted in 59,500 psi. ultimate tensile strength, 43.5% elongation in 2 in., 143 Brinell hardness, and 61,500, 43.5, 121 respectively. Specification requirements are 55,000 to 65,000 tensile strength, and min. elongation in 2 in.: 1,750,000 ÷ tensile strength, and no requirement for hardness.

Both the chemical and physical properties of the shell plate were within the limits specified for firebox grade A.S.T.M. A70-44 steel. Microscopic examination through the cracked sections of plate, weld and flange, Fig. 3, 4 and 5 respectively, showed the cracks to be of intercrystalline nature.

For caustic cracking to occur the metal must be either under applied or residual stress in a corrosive environment.* Sludge collected on the bottom of the reboiler was analyzed chemically. It was found to have an alkalinity equivalent to 5.7% free caustic.

The stresses involved were of residual origin; namely, due to cold rolling the steel plate into a cylinder, and to the thermal stresses resulting from welding. The location of the cracks in the vicinity of the weld and their direction indicate that the welding stresses are the principal ones involved, since it is well known that, in welding, the stresses parallel to the joint are usually the

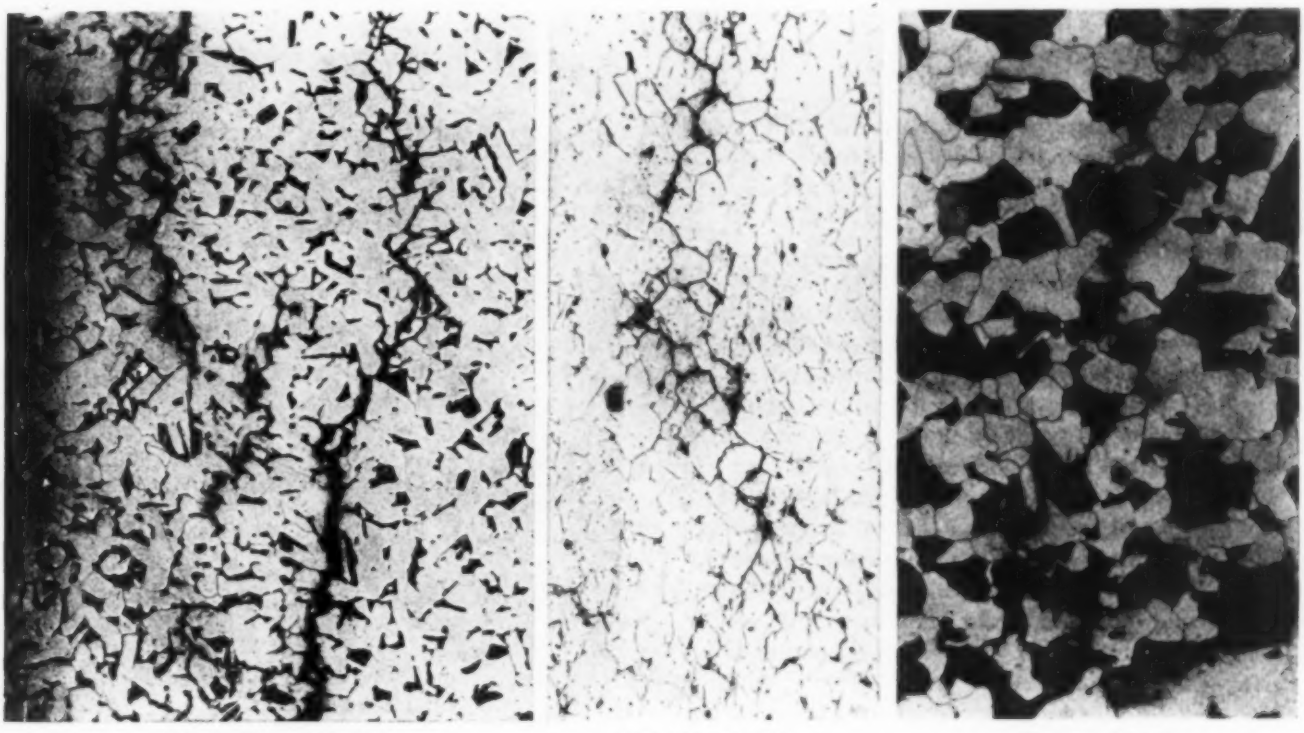
*Editor's Note — Caustic embrittlement of steam boilers has caused great damage to locomotives and stationary power plants in America and has been under active investigation for 35 years. The cracks are mainly intercrystalline (although transcrystalline fissures also occur) and appear at riveted seams. Cracks apparently start in metal highly stressed in tension and at places where small leaks permit the soluble salts carried in the boiler water to concentrate in capillary spaces on faying surfaces or around rivets. Saturated solutions of caustic soda together with a little silica are the ordinary culprits. The palliatives are usually the chemical treatment of feed water to reduce its pH value, or the use of organic inhibitors, plus constant testing of water supplies by detectors able to indicate the ability of the natural water to cause such cracking. A preventive often urged by welding engineers is the elimination of riveted seams by all-welded construction.

greatest and these may be, and usually are, of a magnitude equal to the yield point of steel.

Thus the two main factors causing caustic cracking have been accounted for. The contributive, additional evidence is *(a)* an intercrystalline type of cracking of continuous nature, *(b)* no evidence of decarburization of the inside surface, *(c)* no brittleness of the metal adjacent to cracks. The latter two factors usually are associated with hydrogen embrittlement.

As a result of this failure three other reboilers in similar service in the same unit were thoroughly inspected, with practically negative results. However, a cover of one of these reboilers was found to have a considerable number of cracks adjacent to the weld connecting the dished plate to the flange. These cracks were also perpendicular to the weld. Evidently this failure is of very selective type, just like many other reported stress-corrosion† failures.

The above information is given in view of the fact that, to our knowledge, there is very little



Shell Plate, 100 × Weld Metal, 350 × Flange, 200 ×

Fig. 3, 4, 5 — Intercrystalline Nature of Cracks Discovered. Nital etch

if anything published on caustic embrittlement of *welded* structures. It is hoped it will stimulate a discussion and bring out more information that may be of value in our further understanding of this phenomenon. While we have done no work that throws any light on the theory of stress-corrosion, the marshaling of facts from service will establish means whereby plausible theories can be tested and reliable preventives adopted.

†EDITOR'S NOTE — Stress-corrosion is a more general term than caustic embrittlement, and represents failures by intercrystalline cracking starting at a metal surface which is under more than a threshold tensile stress combined with the action of a corrosive environment. It can occur in such metals as cold worked brass (cartridge cases are historic examples) and even in metals as resistant as stainless steels. Since noncorrosive surroundings cannot be continuously assured, the usual palliatives depend on the relief of surface stresses, either by heat treatment (annealing) or by mechanical means (compressing the surface by shot-peening), although cathodic protection of the sacrificial type, as by magnesium plates, appears to be quite effective for mild steel. J. T. Waber and H. J. McDonald of the corrosion research laboratory of the Illinois Institute of Technology have marshaled much evidence to support their theory that stress-corrosion cracking *in mild steel* is caused principally by dissolved nitrogen in the ferrite. Any iron nitride, Fe_4N, that may be precipitated at the surface forms a galvanic couple and corrosion starts. Once a minute crack is formed it acts as a stress raiser and the concentrated stresses accelerate precipitation of the nitride, more anodic dissolution, and more cracking. According to this theory, anything which reduces the free nitrogen in the surface layers of the metal — such as the addition of strong nitride formers like aluminum or titanium — will be beneficial in reducing the susceptibility to stress-corrosion cracking in mild steel.

Effects of Germination in C-Alloy Magnesium Castings

By John McCabe and W. H. Sharp
Materials Development Laboratory
Pratt & Whitney Aircraft Div.
United Aircraft Corp.
East Hartford, Conn.

IT HAS BEEN generally well known among manufacturers and users of magnesium alloy castings that C-alloy, a magnesium-base alloy containing nominally 9% aluminum, 2% zinc, and 0.2% manganese, is subject to local abnormal grain growth or "germination".

A. T. Peters, R. S. Busk, and H. E. Elliott, in their recent paper "Factors Affecting Abnormal Grain Growth in Magnesium Alloy Castings" (*Transactions* A.I.M.E., June 1945) established that germination and grain growth readily occur during heat treatment of cast magnesium alloy which contains more than 7.5% aluminum and which has, by reason of superheating and chilling, a very fine as-cast grain size. These metallurgists also observed that the only internal stresses necessary for germination and grain growth were those which normally occur as a result of contraction during cooling. They showed that the use of a chill wash (a thin insulating coating) on chills, and special, short, heat treating cycles, prior to normal solution heat treatment, were both effective in suppressing the effect.

Some time ago, during the lathe cutting of the faces of some C-alloy sand castings at Pratt & Whitney Aircraft, the metal chipped or tore rather severely, thus rendering the castings unfit for use in aircraft engines. When we etched the castings with 10% nital we found very large grains exposed on the torn surfaces. This phenomenon is shown in Fig. 1 and 2. It was also noted that germination had occurred at locations where chills had been used. Differences in hardness between germinated and normal areas, Brinell 73 to 75 as opposed to 76 to 79, were too small to account for the machining difficulty.

Fig. 1 — Torn Areas on Machined Surfaces of Large C-Alloy Sand Casting. Surface etched with 10% nital

As may be seen in Fig. 3, tearing was discontinuous and was confined to individual grains which ran as large as ¾ in. across. The direction of the tears was approximately perpendicular to the direction of machining, and apparently followed crystallographic axes of the grains. A section, Fig. 4, taken at an initial magnification of 250 diameters but reproduced at 125, shows a number of tears which were observed in a single germinated grain.

Some of the factors which contributed to germination and grain growth in these castings were as follows:

The castings had been poured from metal which normally contained about half scrap metal, and the melt was presumably superheated at

1700° F. for 15 min. Presence of remelted scrap as well as superheating have been shown to contribute to germination in castings. The castings had been solution treated at 770° F. for 48 hr. and subsequently aged at 400° F. Quantitative spectroanalyses disclosed that the germinated areas contained 8.6% aluminum, approximately 0.5% higher than in fine-grained ungerminated areas. This aluminum content was well above the value of 7.5% established by Peters and his associates as the minimum essential for germination. Furthermore, measurement of the as-cast grain size in areas surrounding those in which germination had occurred — fine as-cast grains surround

Fig. 2 — Germinated Areas Around Top Core Hole of Fig. 1 (Natural Size)

the germinated grains — revealed that it was less than 0.005 in., a size known to be the maximum which would germinate.

Although we were aware that tensile properties of germinated magnesium alloy were substantially impaired — Peters, Busk, and Elliott referred to ultimate strengths of half the normal value — we were interested in confirming this pronounced effect. We also thought it desirable to determine the effect of germination upon the endurance limit. Since the germinated layer ran as deep as ¼ in., it was possible, by means of macro-etching and careful machining, to obtain a number of strip tensile and Krouse sheet fatigue specimens with coarse-grained areas oriented at points where fractures would be expected to occur. For purposes of com-

Direction of Machining→

Fig. 3 — Relation of Tears to Direction of Machining and Orientation of Grains. Glycol etchant, 2 ×

parison, a number of tensile and fatigue specimens were machined from those portions of the castings with normal grain size.

Two of the fractured tensile specimens are shown in Fig. 5. The specimen which is germinated over a relatively small area fractured through this area although the width of the specimen was 0.004 in. less at the midpoint of the gage length. Also, it may be observed that the other specimen fractured where the grains were larger than elsewhere. Table I shows the effect of germination upon the tensile properties of solution heat treated and aged C-alloy. Although there was some scatter in our test results, probably due to variations in orientation and size of grains, we have averaged the values for tensile and yield

Fig. 4 — Transverse Section Through Machining Tears in a Single Germinated Grain. Glycol etchant, 125 ×

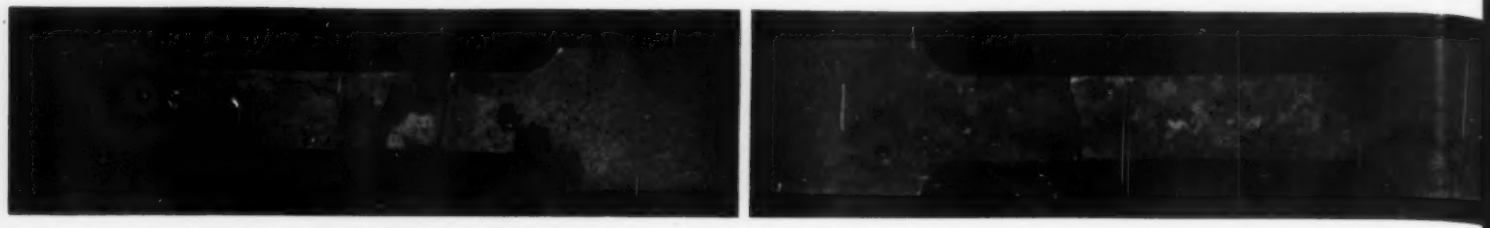


Fig. 5 — Fractures Through Germinated Areas of Strip Tensile Specimens 5/8 In. Wide. Etchant: 10% nital

strengths and for elongation. That germination has a pronounced harmful effect upon tensile properties is indicated by the 43% loss in tensile strength, 23% loss in yield strength, and 67% loss in elongation. Certainly such values suggest that fatigue properties would also be lowered.

Table I — Effect of Germination on the Tensile Properties of Sand Cast, Heat Treated, C-Alloy

	Normal	Germinated	Loss
Tensile strength, psi.	43,500	24,925	43%
Yield strength, psi.	23,700	18,175	23
% Elongation in 2 in.	4.30	1.40	67
Brinell hardness (500 kg.)	76 to 79	73 to 75	4

Fig. 6 — Fatigue Fracture Through Germinated Grains in Krouse Specimen. Specimen shown full size; inset shows fractured surface at 5 ×

Typical of the fractured fatigue specimens, which were etched to reveal the relationship between coarse grain and fracture after testing, is the one illustrated in Fig. 6. The cleavage-type fracture, which was partly transgranular and partly intergranular, immediately suggests subnormal fatigue values. Although it was difficult to machine fatigue specimens from germinated areas, due to the size and shape of the Krouse sheet specimens, sufficient tests were run to indicate a definite trend. This is shown in Fig. 7. The upper line is the endurance curve for normal (not germinated) C-alloy, solution heat treated and aged. A stress value of about 14,000 psi. at 100,000,000 cycles is in good agreement with available data for this alloy. For purposes of simplification a similar curve (the lower one) has been drawn through four of the five points obtained in our laboratory with germinated specimens. A decrease in stress of roughly 4000 psi. (30%) in the stress level at 100,000,000 cycles appears probable.

During the course of this investigation the possibility of recovering the normal fatigue properties (by stressing or deformation, or both, with

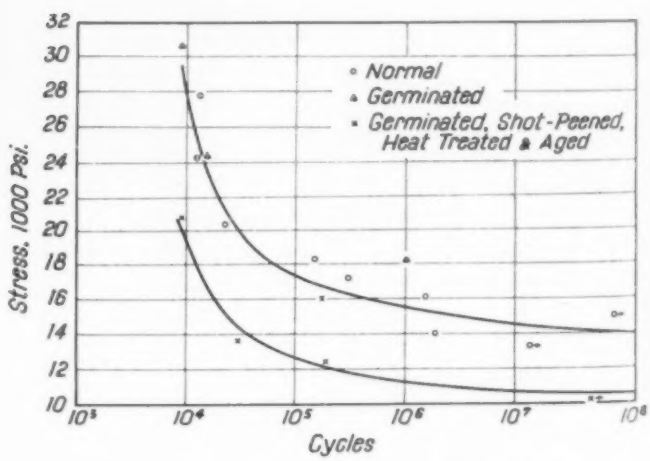


Fig. 7 — Germinated C-Alloy Has Notably Lower Endurance Than Fine-Grained Alloy. Properties are restored by shot-peening and heat treatment

subsequent recrystallization) was considered. A number of germinated specimens were shot-peened with malleable iron shot to an intensity considerably in excess of those ordinarily used for increasing the fatigue life of magnesium alloy. High peening intensities were used since a deep effect was desired. The specimens were then subjected to solution and aging treatments, and some of them were sectioned for examination. Figure 8 shows the condition of the germinated layer after this treatment; a recrystallized surface layer of relatively fine-grained metal had been produced. Grain size of this recrystallized layer, obviously, was variable by reason of the reduced amount of deformation from the surface inward. Maximum depth of the fine-grained layer was about 0.050 in.

When coarse-grained (germinated) fatigue specimens were shot-peened, solution heat treated and aged, and the surfaces machined to remove the indentations, it was observed that recovery of fatigue properties took place as indicated by the three plotted points in Fig. 7. These lie slightly above the curve for the fine-grained, solution treated and aged C-alloy.

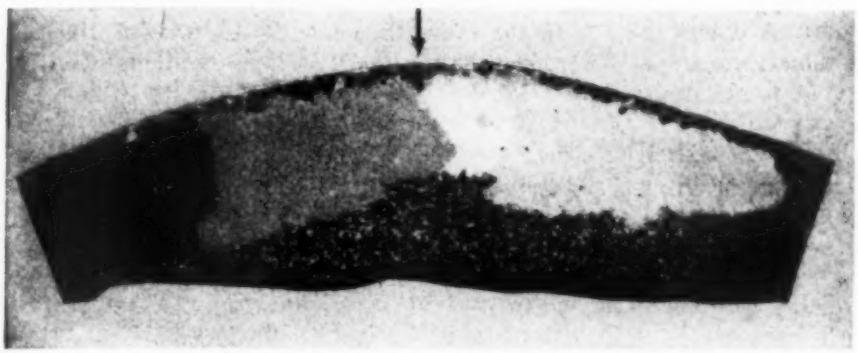


Fig. 8 — Cross Section of a Germinated Specimen of Cast C-Alloy After It Has Been Heavily Shot-Peened, and Then Subjected to Normal Solution Treatment and Aging. Glycol etchant, 3 ×

In conclusion, it has been confirmed that germination (excessive grain growth) has a pronounced harmful effect upon the tensile properties of the cast magnesium C-alloy; furthermore, it has been shown that germination substantially lowers the normal fatigue properties. By shot-peening, solution heat treating and aging, a germinated magnesium alloy has its fatigue properties fully restored to normal values.

Bits and Pieces

Preparation of Alumina Abrasive

FOR the classification of alumina into uniformly sized particles for metallographic polishing, the National Bureau of Standards has used the method described by J. L. Rodda in *Transactions*, A.I.M.E., Vol. 99, 1932, p. 149. In this method the alumina is first dispersed in a pebble mill with water, using sodium silicate as a peptizing agent. The suspension is allowed to settle for a definite period and a predetermined amount siphoned off. Fractions taken in this manner supply several different grades of sized alumina for polishing various metallic specimens.

Since considerable amounts of alumina are prepared at one time in our laboratories, the more rapid settling of these fine-sized fractions for storage has been a problem. Such concentration has been accomplished by adjusting the hydrogen ion concentration to a value which caused flocculation. This sometimes required considerable manipulation, involving small additions of acid or alkali to obtain an apparently critical hydrogen ion concentration.

We have recently found that the use of a synthetic detergent, known commercially as Dreft, will bring about rapid flocculation and settling of the alumina. One teaspoonful (about 1.5 g.) of the detergent is added to 3 l. of the suspension, which is then acidified with a few drops of concentrated hydrochloric acid. After the particles have settled (which takes only a few minutes)

the liquid is siphoned off and the alumina washed several times by decantation until the wash water gives a neutral reaction. Caking of the alumina is also prevented by this flocculation treatment. (HARRY STERN and PAUL R. TOTTEN, National Bureau of Standards)

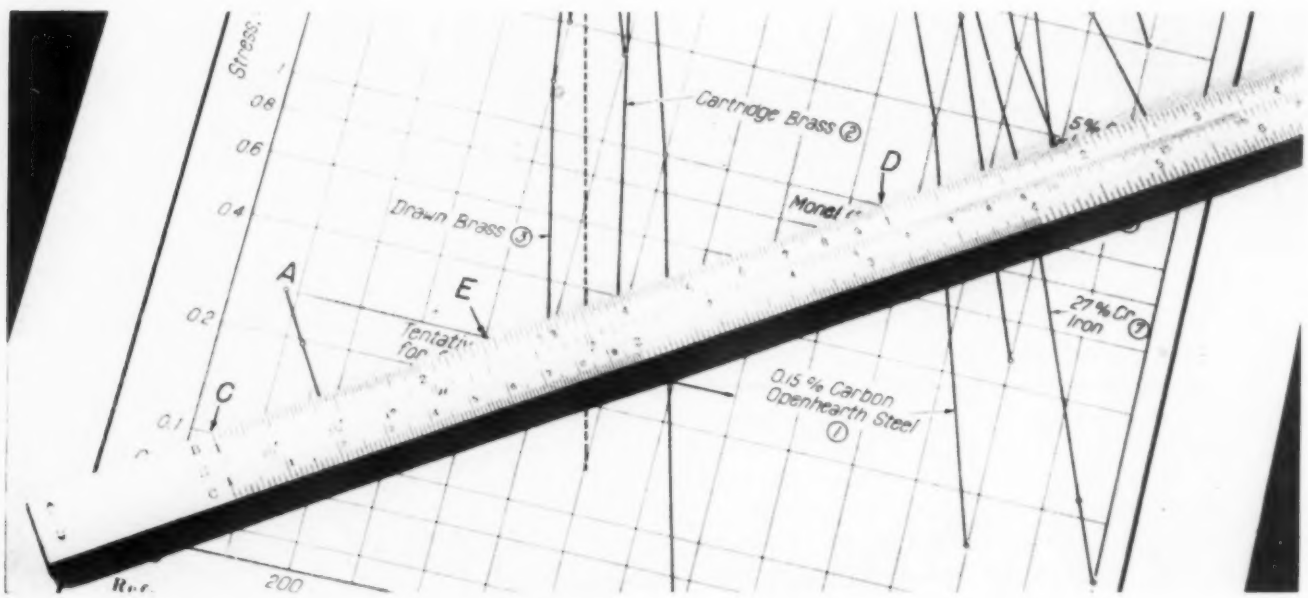
Logarithmic Scales of Odd Lengths

IT IS EASY enough to plot or read points on semilog or log-log paper, for the coordinates are ruled close enough together for accurate interpolation by eye. It is a different problem when a person is working with a printed reproduction of such a graph, for the multitude of intermediate lines are then missing, and the scale of the reproduction may be almost anything. For example, suppose a definite figure for the creep strength of lead at 70° F. (point *A* on the accompanying engraving) be required from the Data Sheet in *Metal Progress* for March 1947. The logarithmic scale is changing so rapidly between 0.2 and 0.4 that a proportional estimate would obviously be quite wrong.

To meet this contingency it is only necessary to take the slide from a slide rule, or cut a strip from semilog paper, and lay it across the diagram in such a way that a complete modulus is matched on the two. In the illustration, Scale B on the slide will serve. Pivot the end-mark on some point on the 0.1 horizontal of the diagram *(C)*, and swing the slide until the other end of the modulus coincides with the 1.0 horizontal on the diagram *(D)*. Note, now, that the 0.2, 0.4, 0.6 and 0.8 horizontals intersect the appropriate marks on the slide rule slide. A horizontal line through the unknown point *A* will then intersect the diagonal scale at the correct reading — namely, 0.257 at point *E*. The required figure for creep strength of lead at room temperature is therefore 2570 lb.

The only thing to watch out for is that one complete modulus on the diagram — for example, 0.1 to 1.0, 1.0 to 10.0, or 10 to 100 — must match with one complete modulus on the logarithmic scale you are using.

In the event the scale of the printed diagram is too large or too small for any available logarithmic scale, values can simply be located by determining their logarithm. For example:



Slanted Slide Rule Slide for Estimating Intermediate Positions on Logarithmic Plots

Vertical distance 0.1 to A = 1.02 in.
Vertical distance 0.1 to 1.0 = 2.46 in.

Then $\frac{\log A}{\text{modulus}} = \frac{1.02}{2.46}$

By slide rule, $\log A = 0.414$

Set 0.414 on the log scale (usually on the back of the slide), and read A as 0.259 from Scale D on the slide rule's face.

To plot points, rather than scale them, the procedure is merely the converse of that given.

CHARLES K. DONOHO, the mathematically-minded chief metallurgist of American Cast Iron Pipe Co., also calls attention to the need of logarithmic scales of odd modulus-lengths for the preparation of spectrographic analysis charts to

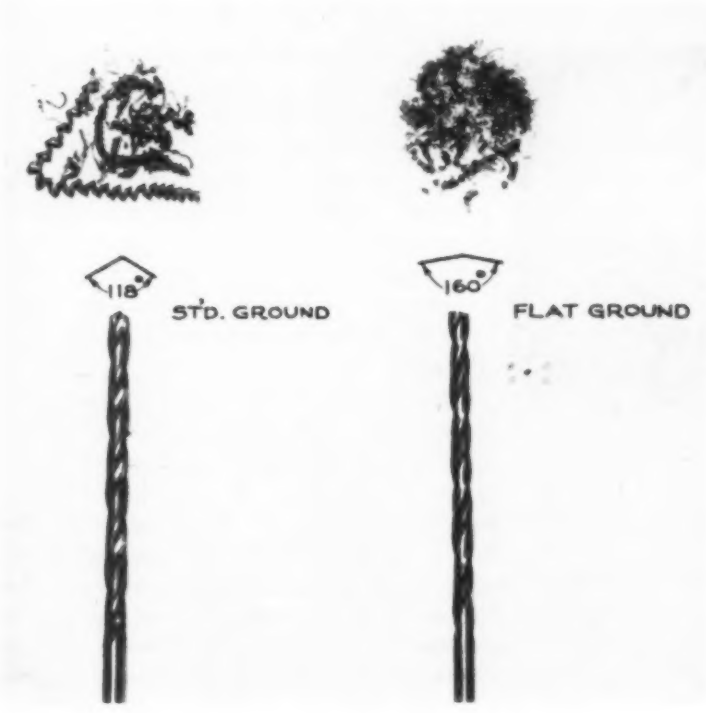
read from intensity ratios to % of element. He photographed the B and C scales of a 20-in. slide rule (at sufficient distance to minimize distortion), then projected from the negative at various enlargements to make a series of prints of scales with modulus lengths varying all up and down the line. These prints have been very useful in selecting log scales to fit data, and would be very handy for fitting exactly a predrawn scale by the "slanting scheme" described above.

Chips for Chemical Analysis

WHEN a piece of steel or other metal is to be analyzed, the chemist sometimes receives a handful of long, curly, unmanageable chips. These chips are difficult to work with and take more of the chemist's time than an analysis would normally require.

There are many laboratory workers who are not aware that fine, short chips can be easily obtained by grinding the tip of an ordinary drill nearly flat. As shown, the standard drill with a 118° included angle results in long, curly chips, while a drill whose tip has been ground to an included angle of 160°, gives the desired fine chips. The exact angle is not important.

Increasing the drill speed and using a light pressure will produce even finer chips. (C. O. LUNDBERG, Research Laboratories, Norton Co.)



A Temporary Holder for Polishing Metal Specimens

DURING a recent study of the catalytic activity of plane faces of copper single crystals it was necessary to polish metallographically thin slices of irregular shape. Since both sides of the slice were to be polished and the slice had to be removed at intervals for etching, it was impracticable to mount it in plastic. The following method of support was found to be very satisfactory:

A rectangular piece, slightly larger in area but appreciably thinner than the copper slice, was cut from a sheet of "Plexiglas" and the outline of the metal specimen was scribed on it with a metal stylus. The inscribed area was then cut from the center, using a scroll saw. Several solid pieces of Plexiglas of identical *exterior* dimensions were cemented to the first piece by wetting one surface with a few drops of acetone and clamping them together until dry; the back of the first slice thus rested on the second piece of Plexiglas, and formed a depression that fit the copper slice. A handle was fashioned on the backing by cementing several pieces of smaller cross-sectional area to the larger pieces.

One side of the copper slice and the receptacle in the holder were then coated with a thin layer of rubber cement. After air drying to tackiness — a few minutes — the metal slice was firmly pressed into the depression in the mount.

The adherence between the Plexiglas mounting and the metal slice was excellent and no trouble was ever experienced due to the slice slipping out of the mount. When work on one side is finished, the slice is readily pried loose from the mounting, and the excess rubber cement can be rubbed off with the fingers. (HENRY LEIDHEISER, Jr., research chemist, University of Virginia)

Selective Annealing of Nonferrous Metals

DURING the past few years (since there have been so many metal shortages) it often became necessary to purchase substitute materials to be used wherever possible. For example, if spring temper brass or phosphor bronze were the only grade obtainable and the part specified called for half-hard stock, it was found easy to blank out the parts and then anneal the blanks to half-hard temper. It was sometimes found

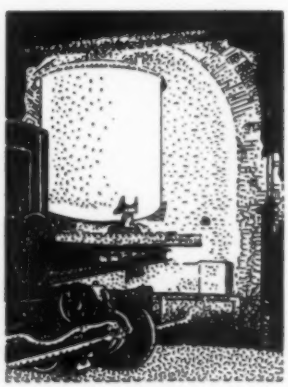
necessary, with progressive dies, to anneal the full-length strip to the desired temper. A very complete set of annealing curves for copper-base alloys will be found in the book "Copper and Copper-Base Alloys" by Wilkins and Bunn. Using these annealing curves and allowing 1 hr. per in. of load for heat penetration, it was found possible to anneal to plus-or-minus two points on the Rockwell B scale.

Another example was found when efforts were being made to form a difficult nickel-silver spring from 8 numbers hard material; fractures occurred wholesale. A check of the Rockwell hardness of the material showed it to be at the maximum for the temper specified. The parts when annealed to the minimum for 8 numbers hard material were formed without difficulty.

Tempering curves have also been set up for cold rolled steel, so that it is possible to anneal it to any specified hardness as desired. Where it was found necessary to harden parts made from cold rolled steel, this was done by quenching from 1750° F. into water. With this treatment we could bring dead soft material up to "hard" temper. (L. H. SEABRIGHT, manufacturing methods engineer, Kellogg Switchboard & Supply Co.)

Adherence of Enamel

DEGREE of adherence of the porcelain enamel ground coat to base metal has always been considered an important criterion of its ability to perform satisfactorily in service. Its accurate evaluation, however, has been difficult. Usually a coated sheet metal specimen is placed over a circular die and cupped by forcing into it a spherical head. This cracks off a certain amount of the enamel and the amount of bare metal, proportionate to the entire test area, is used to place the enamel in one of several broad classifications as to quality.



Attempts to secure a precise method of classification have involved the use of ferroxyl indicator gels, resistance measurements of a cell in which the specimen formed one electrode, reflectance measurements, and microscopic analysis of the deformed area. Such methods were not widely adopted because of the difficulty in controlling variables, or the excessive time required.

Normally, a porcelain enamel coating is an electrical insulator. The basic principle of the new instrument developed at the National Bureau of Standards depends on the completion of an electric circuit through the bare metal of the deformed specimen to a steel probe touching the test area. By using a large number of probes, and counting the number which conduct a current during the test, an estimate can be obtained of the area which has been exposed.

The test instrument consists of three major parts — stand, test head and control cabinet. The stand has a base plate, specimen holder and vertical column on which the test head may be raised and lowered. The test head is made of a plastic block pivoted to a metal holder, and an elevating mechanism. The plastic block contains 169 holes, arranged in a hexagonal, close-packed pattern, the distance between centers being 0.100 in. Each hole is fitted with a probe-bearing assembly which is free to move vertically against its own beryllium-copper spring. This spring makes an electrical contact between the probe and a wire connected to an individual segment of the selector switch located in the control cabinet.

The steel probes can be lowered on slightly different locations of the same test cup by pivoting the test head from one to another of five stop positions spaced 7½° apart. Since the pivot of the test head is located eccentrically with respect to the cupped portion of the test piece, the possibility of any one probe following the same circular fracture is minimized, and the multiple count for the five stop positions increases the precision of the measurement.

The control cabinet contains a power supply, relay, selector switch, and magnetic counter. In operation, a ground wire is clipped to the specimen to be tested, and the test head lowered onto the deformed area which has been positioned below it with the aid of a guide, until all of the probes make contact with the specimen. A synchronous motor drives the selector switch, and the circuit through each probe is tested individually as the arm rotates. The test cycle, started manually, is stopped automatically after the last circuit is tested. For each needle which touches bare metal, the relay actuates the magnetic counter.

The number recorded on the counter may be used for direct comparison of two specimens or, if desired, the exposed and coated portions of the test area may be readily computed, and the coated fraction used as an index of adherence. (ALLEN C. FRANCISCO, research associate, Porcelain Enamel Institute, National Bureau of Standards)

The Heat and Mass Flow Analyzer —a Tool for Heat Research

By Victor Paschkis
Technical Director
Heat and Mass Flow Analyzer Laboratory
Department of Mechanical Engineering
Columbia University, New York City

The mathematical formulas for heat flow in solids and electrical flow in certain types of circuits have the same form. Consequently, heat flow problems can be studied by electrical measurements in appropriate combinations of resistances and capacitances. Many metallurgical problems concerning furnace construction, operation of controls, solidification of ingots and castings, and heating of various masses of metal have been studied in this way; results of several have been satisfactorily verified both by direct experiment and by mathematical computation.

A GENERAL SURVEY of the characteristics in engineering research in modern times shows two features: Widespread use of calculating machines and the use of teamwork.

Calculating machines are used not only to alleviate the burden of computing numerically complicated equations, but also to solve equations which cannot be solved by the human brain by normal mathematical procedures.

The necessity for teamwork springs from specialization. Every industrial process, under today's conditions, incorporates features which are common to many different fields. With the increasing complexity of each of these fields, results can be hoped for only through concerted action by specialized research workers.

The Heat and Mass Flow Analyzer Laboratory at Columbia University is based on both of the trends mentioned above. It it a calculating machine specializing in one field, namely heat and mass flow. The transmission of heat from one body to another (and, contrariwise, the prevention thereof) is obviously a matter of prime interest to metallurgists. The importance of "mass flow" is not so apparent, but a typical example for mass flow in metallurgical work is the diffusion of solids in metals. This diffusion obeys the same mathematical laws as heat flow and is therefore amenable to analysis by the electric analogy method.

In industry, "heat flow" may be generally regarded as a forgotten child. Because so relatively little is known about heat flow, problems which actually belong to this field are often not recognized as such, and by mistake are classified together with other problems under different names. Often the actual solution of the heat flow aspect of the problem is still done empirically.

One reason for the lack of work on heat conduction problems is the difficulty of solving them. By and large, three methods to explore such problems are available: *(a)* Direct experimentation (by making temperature and heat flow measurements), *(b)* mathematical analysis and *(c)* analogy methods.

Considering the first of these, it can be said of research work in general and thermal research work in particular, that direct experimentation rarely lends itself readily to systematic investigations. The difficulties encountered in making accurate temperature measurements at the exact

position desired, the expense of systematically varying the material and shape of the object, the inconvenient time periods (extremely fast or slow processes), the reluctance to interrupt production for experimental purposes — all these tend to make direct research difficult and oftentimes impossible.

Mathematical analysis, besides being inapplicable to many problems, is — even if technically feasible — frequently too time-consuming for practical purposes.

Among the analogy techniques, the electric analogy method is of particular interest and is treated in the balance of this paper. The use of lumped resistance-capacitance circuits for heat flow studies was first suggested* by C. L. Beuken, who in tireless work developed the method and built the first model. Based on his ideas, the technique has been perfected and developed in the Heat and Mass Flow Analyzer Laboratory at Columbia University.

Principle of the Analyzer

The heat and mass flow analyzer is based upon the electric analogy method, using concentrated or lumped parameters.

In order to explain this descriptive statement, first consider the basis of the electric analogy method. It so happens in nature that the mathematical laws expressing the flow of heat in solids are identical with those expressing the flow of current in circuits having evenly distributed resistance and capacitance. Therefore, it is possible to substitute an electrical system for an entirely unrelated physical system. Electrical measurements are very much more easily carried out than thermal measurements, and this alone would be a tempting reason to make such a substitution.

There is, however, still a second reason which serves as an inducement: In electrical measurements it has been customary for many years to use the "lumping" or "concentrating" procedure. Instead of carrying out measurements on a body having *evenly* distributed properties, measurements are carried out in a circuit in which the properties of the body which is to be investigated are concentrated in individual circuit elements or lumps, such as resistors or capacitors. The sections or lumps are built up of more or less standard elements, and may be combined at will, as need arises, by appropriate switches and cross connections.

The method can be explained by the upper diagram of Fig. 1, which represents a metal rod insulated at its sides and exposed to ambients on two faces, the two ambients having temperatures of 100 and zero degrees, respectively. Flow of heat in such a rod could be studied by measurements on an electric cable, shown in the central sketch of Fig. 1, the cable having evenly distributed resistances and capacitances. The step of lumping is represented at the bottom of Fig. 1. The cable is thought of as being divided into sections or lumps, and the resistance of each section is measured and represented by a resistor in the circuit, while the capacitance of each section is represented by a capacitor in the circuit. Finally, we can think of the rod itself as being divided into sections, and correlate each of its sections with a corresponding part of the circuit shown at the bottom of Fig. 1.

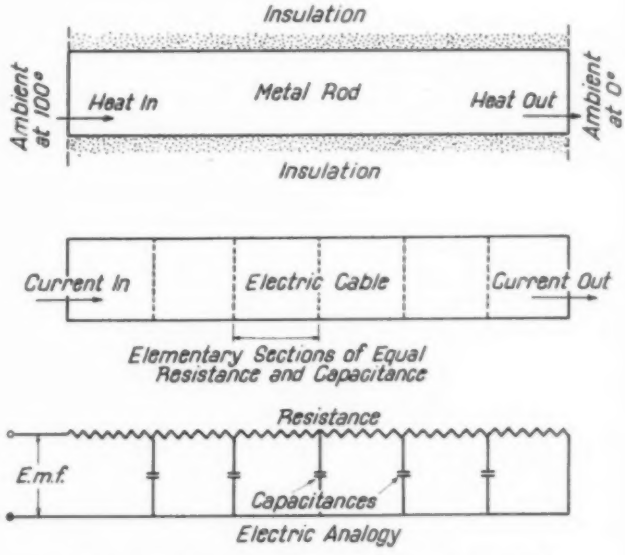


Fig. 1 — Sketch Showing Electric Analogy Method for Studying Heat Flow

It is interesting to study the analogies and the corresponding magnitudes between the electrical and the thermal systems in the form of a table:

Electrical Magnitudes	Thermal Magnitudes
Volt (v.)	Temperature difference (F.)
Current (amp.)	Rate of heat flow (B.t.u./hr.)
Electric resistivity (ohm-ft.)	Thermal resistivity (ft., hr., F./B.t.u.) or (1 ÷ conductivity)
Electric capacity (microfarad/cu.ft.)	Thermal capacity (B.t.u./cu.ft., F.) or (density × specific heat)
Electric charge (amp-sec.)	Heat content (B.t.u.)

Any consistent set of dimensions can be used. A typical set of dimensions is shown in parentheses for each magnitude.

*In an article in *Economish Technish Tijdschrift* (Maestricht, Netherlands), No. 1 for 1937.

An extremely important feature of the electric analogy method is that it is not necessary to carry out the electrical experiments in the same length of time in which heat flow occurs. A time scale can be applied, increasing or decreasing the time for the electrical experiments as compared with that for the thermal experiments. For example, a study of the temperature rise in a movie film during the time of exposure to the projector arc has been carried out. The actual time of exposure

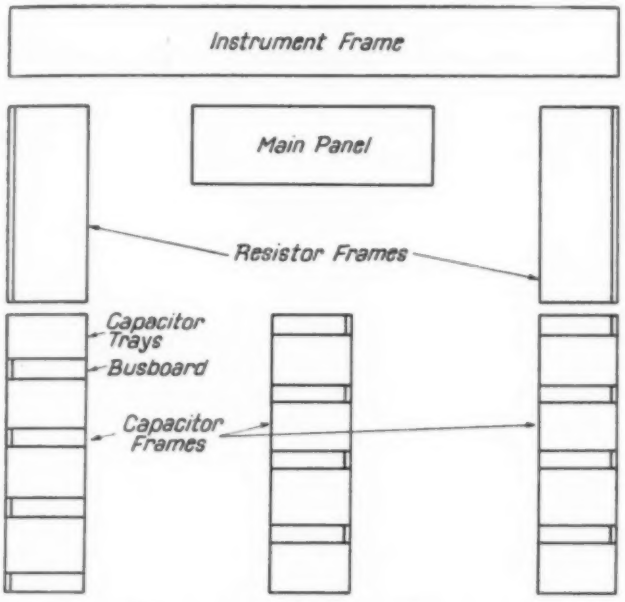


Fig. 2 — Schematic Plan of Heat and Mass Flow Analyzer

is in the order of magnitude of 0.001 sec.; the electric experiments were stretched to last 5 min. or more. On the other hand, the laboratory carried out experiments to determine the temperature rise in an electric cable buried under ground and subjected to varying loads over a three weeks' period. The three weeks were condensed in the electric experiments to less than 5 hr.

Two frequently encountered misconceptions regarding the electric analogy method should be clarified here.

First, it should be understood that in order to carry out the experiments on the heat and mass flow analyzer, samples of the material are not used. (Neither would they be used on a calculating machine if arithmetical methods of solving the problem were available.) It is sufficient to know the thermal (not electrical) properties of the body involved and its size and shape.

Second, it is often asked, by more mathematically minded observers, if it is possible to set up a circuit for which it is impossible to write a mathematical equation. Based on the identity of the fundamental equations, circuits can be designed without writing or even knowing the differential equation. The procedure is similar to that used for graphic solutions or for any other method using finite differences, which may be applied without first developing the differential equation. In fact, the differential equation is seldom written before designing the circuit.

Description of the Laboratory

As would be concluded from the foregoing, the laboratory, by and large, consists of resistors and capacitors arranged so as to permit convenient setup of various circuits; in addition the necessary current measuring instruments and power supplies are provided (see Fig. 2).

Capacitors (condensers) are arranged in three frames, resistors in two frames. Each capacitor frame contains four rows of capacitor trays. Adjacent to each row is a busboard made from insulating material; it has a number of groups of outlets, the outlets of each group being electrically interconnected.

Resistors are arranged in two frames, each frame comprising ten boards, and each board having six resistor sections. A resistor section comprises four decade switches, with the appropriate resistors mounted in back, and with provision made for temporary addition of extra resistors if required.

Each of the busses from the busboards and the resistor sections is brought out to the main panel where all connections required to build the circuit are made. A partial view of this main panel is given in Fig. 3. As seen from the plan view, the instrument panel with all instruments and power supplies is arranged opposite the main panel; connections are made by overhead wires. Principal instruments comprise two two-point and one six-point recording voltmeters, and one six-point recording milliammeter, two voltage regulated power supplies, two constant current devices and a current-time integrator.

The procedure for building a circuit is as follows: First the circuit to simulate a body is set up on the main panel. Then the setting of resistors and capacitors is made on the resistor and the capacitor frames respectively. Finally, the instruments and power supplies are connected, and the experiment is ready to start.

The use of this heat and mass flow analyzer for solving complex heat flow problems encounters limitations which, by and large, can be grouped under two headings:

1. **Shape Limitations.** Theoretically, the use

of lumped circuits in the electric analogy method can be applied to the investigation of a body of any size, shape or material. However, the complexity of the circuit required to represent the body grows rapidly with the irregularity of the shape — not, however, with the size. A large number of sections or lumps is required for an irregular body and the possibility of human error increases rapidly. Therefore, the Heat and Mass Flow Analyzer Laboratory has limited itself so far to the solution of one-dimensional and two-dimensional problems, provided the latter are not too complicated. We hope to develop, eventually, a technique for investigating complex shapes. In the meantime two methods of approximation may be used. One consists of studying a three-dimensional problem by investigating three two-dimensional problems and estimating the mutual influence of the three problems. The other approximation consists of dividing the body into individual parts and analyzing them separately. If, for example, the heating of a body with non-uniform cross section is to be studied, it is sometimes possible to study the temperature rise of the thin part separately from that of the thick part. The mutual influence of the two is frequently of only secondary importance.

2. Lack of Knowledge of Properties. As in any calculating device, the accuracy of results obtained on the heat and mass flow analyzer is no better than that of the properties (data) fed into the machine. Because there was no reliable method for calculating or measuring heat flow, up to recently, properties for many materials were not determined accurately. As a result there is a large gap in our present knowledge of the thermal properties of many materials. To this difficulty three answers may be given:

First: Properties are often known within limits. The ease with which computations can be made on the analyzer makes it economically feasible to run tests several times, each run set up for one limit of one or more of the properties. Say, for example, the conductivity of a given body is known or estimated to be between limits *a* and *b*, and the volumetric specific heat between limits *c* and *d*. Then with a maximum of four experiments, the limits for temperature change and rates of heat flow can be established, the experiments or computations being made for the following combinations of properties: *a* and *c*; *a* and *d*; *b* and *c*; *b* and *d*. For a great number of problems the number of experiments for these conditions could even be cut down to two.

Second: It is of course possible to determine experimentally the properties — thermal conductivity, specific heat, density, boundary conductance (sometimes called film conductance) — for the material or materials involved. The heat and mass flow analyzer can be of considerable help in the following manner: Families of curves are set up by systematically varying all properties involved over a considerable range of values. Thus, an "order of influence" can be established for the various properties. Once it has been established which properties are of greatest importance, it is not too difficult to establish by conventional physical test methods those properties which exert the greatest influence on the results.

Third: It is possible to "operate the heat and mass flow analyzer in reverse" and use it to establish properties. By and large this seems worth while whenever temperatures can be measured more easily than thermal properties.

Verification

Although the validity of the method can be proved mathematically, it is understandable that the request for an *experimental* proof is raised frequently. Such proof can be given by comparing results obtained by direct experiments or mathematics with those obtained on the analyzer.

Such proof has been given time and again, and rather than reprint figures previously published, the following list contains seven publications, the illustration in the article in which the comparison is presented, the nature of the comparison, and the agency carrying out the check.

Perry A. Berggren of the University of California verified the results of an analysis by direct experiments; his findings are shown in Fig. 5 of "A Method for Determining Unsteady State Heat Transfer" by V. Paschkis and H. D. Baker, a paper printed in *Transactions* of the American Society of Mechanical Engineers, Vol. 64 (1942), p. 105.

In *Transactions* of the American Society of Heating and Ventilating Engineers, Vol. 48 (1942), p. 75, is an article by the present author in which is shown (Fig. 6 and 9) checks between results obtained by direct experiments in the Society's research laboratory and results obtained on the heat and mass flow analyzer.

Comparison of electric analogy results and mathematical analysis is given in Fig. 2 and 4 in "Application of an Electrical Model to the Study of Two-Dimensional Heat Flow" by M. Avrami and V. Paschkis, *Transactions*, American Institute of Chemical Engineers, Vol. 38 (1942), p. 631.

Johns-Manville Corp.'s laboratories checked the analyzer's results experimentally. See Fig. 3 of "Analyzing Heat Flow in Cyclic Furnace Operation" by C. B. Bradley and C. E. Ernst. *Mechanical Engineering*, Vol. 65, p. 125.

W. F. Hess of Rensselaer Polytechnic Institute verified experimentally the establishment of cooling curves of welds by means of electrical analogy. (See Fig. 15 and 16 of a paper by V. Paschkis in *Welding Research Supplement*, Vol. 8, 1943, p. 462-s.)

"Studies on Solidification of Castings" (a paper by the present author in *Transactions* of the American Foundrymen's Assoc., Vol. 53, 1945, p. 90) were checked experimentally by C. L. Clark of the Naval Research Laboratory. See Fig. 1, 2, 4, 5 and 6 in the publication quoted.

In another study by V. Paschkis and M. P. Heisler (*Journal of Applied Physics*, Vol. 17, 1946, p. 246) experimental results were checked against the mathematical.

Applications

The laboratory, operating since the spring of 1941, and having its facilities increased twice, has worked on so many different problems that no attempt is made to give a complete list of the investigations handled by it for various industries. The bibliography appended can be consulted for that purpose. The following examples are indicative of the kind of problems handled.

Steel Industry.

1. Some studies on openhearth regenerators were carried out for a large steel producer. The investigation examined the influence of the length of the reversal period, thickness of the brick, and size and shape of the flue channel. As a result a new regenerator was designed.

2. For the National Defense Research Council —a study of ingot solidification, which contributed to better utilization of the steel in the ingots.

3. In a cooperative program with S.K.F. and Lukens Steel Co. a first survey of temperature-time curves in hardening was conducted.

Foundry Industry.

1. The Heat and Mass Flow Analyzer Laboratory has been engaged for the last few years in studies of the solidification of castings, in a cooperative program with the American Foundrymen's Assoc.

2. As a first step, the predictions of freezing rates from the analyzer with those obtained by "bleeding tests" were compared. (Bleeding tests consisted in dumping partly solidified castings at specified times, and measuring the thickness of the frozen skin.)

3. Then the influence of different properties of steel on the solidification rate was tested.

4. As a further step, solidification of white cast iron and of aluminum was investigated.

5. Ultimately a shop instruction on solidification will be issued.

Furnace and Refractories Industry.

1. The influence of "thermal short circuits" on the value of insulation was tested and presented in fairly general curves.

2. Heat losses from intermittently operated furnace walls were investigated for the Johns-Manville Corp., enabling that firm to render better service to the customers.

3. Heating-up time and heat losses during the starting period have been investigated.

Mechanical Industries.

1. Temperature distribution in wheels and brake shoes of locomotives were studied for a brake shoe manufacturer.

2. Temperature distribution in brake shoes and brake linings of airplane wheels were investigated for an airplane manufacturer.

3. Cooling in arc welding was studied for the National Defense Research Council.

Refrigerating Industries.

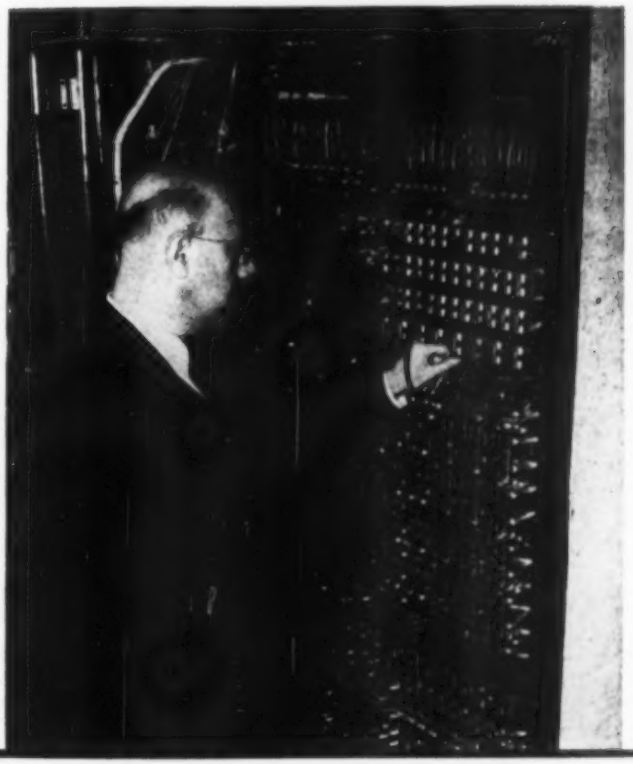
1. Temperature distribution in the wall of a refrigerating chamber was studied for E. I. du Pont de Nemours & Co. The wall is composed of different materials, with irregular mortar joints, causing hot and cold spots and subsequent formation of dew.

Instrument Industries.

1. A study of the accuracy of on-off control in electric resistor furnaces has been completed.

2. In cooperation with the research committee of the American Society of Mechanical Engi-

Fig. 3 — The Author Plugging in a Connector on the Main Panel



neers, a study of the fundamentals of temperature control has been initiated and is now in progress.

Glass Industry.

1. Distribution of temperatures and temperature gradients in heated airplane windows was studied for the Pittsburgh Plate Glass Co. Information regarding the best distribution of heater wires was obtained.

2. A study of temperature gradients in forming containers for glass was initiated and is in progress at this time.

General Investigations.

A very important function of the Heat and Mass Flow Analyzer Laboratory is to set up charts and graphs of general interest.

1. A considerable extension of range, accuracy and readability of the so-called "Gurney-Lurie Charts" has been completed.

2. Curves permitting the determination of the rate of temperature change directly, rather than from time-temperature charts, have been established.

Bibliography

"Electrical Machine Solves Heat Transfer Problems", by Philip W. Swain. *Power*, V. 85, 1941, p. 480.

"Application of an Electric Model to the Study of Two-Dimensional Heat Flow", by M. Avrami and V. Paschkis. *Bulletin* of American Physical Society, V. 16, p. 15.

"New Heat Transfer Research Tool", by G. Stetson. *Mechanical Engineering*, V. 64, 1942, p. 95.

"A New Method of Solving Problems of Heat Flow Through Solids", by V. Paschkis. Lecture before New York Chapter of A.S.M.E., Feb. 10, 1942.

"Electrical Analogy Method for the Investigation of Transient Heat Flow Problems", by V. Paschkis. *Industrial Heating*, V. 9, p. 1162.

"Heat Transfer Problems Solved by Roomful of R-C Networks". *Electronics*, April 1943, p. 180.

"Heat Transfer Problems Solved by Electrical Analyzer". *Production Engineering*, V. 14, 1943, p. 442.

"Complex Heat Transfer Solved by Electrical Analogy". *Chemical and Metallurgical Engineering*, V. 50, 1943, p. 111.

"The Accuracy of Measurements in Lumped R-C Cable Circuits as Used in the Study of Transient Heat Flow", by V. Paschkis and M. P. Heisler. *Electrical Engineering*, V. 63, 1944, p. 165.

"Industrial Electric Furnaces", by V. Paschkis. *Industrial Heating*, V. 11, 1944, Part I, p. 52; Part II, p. 226; Part III, p. 362; Part IV, p. 558 and 738; Part V, p. 902; Part VI, p. 1430.

"Temperature Distribution on the Surface of a Brick Wall With Mortar Joints", by V. Paschkis. *Refrigerating Engineering*, V. 47, 1944, p. 469.

"The Influence of Through Metal on the Heat Loss From Insulated Walls", by V. Paschkis and M. P. Heisler. *Transactions* of A.S.M.E., V. 66, 1944, p. 653.

"Remarks on On-Off Control in Resistor-Type Furnaces", by V. Paschkis. Annual Meeting of A.S.M.E., New York, Nov. 27, 1944.

"Measurement of Heat Absorption in Furnaces", by V. Paschkis. Symposium at the A.S.M.E. Annual Meeting, New York, 1944. Reprinted in *Industrial Heating*, V. 11, 1945, p. 402 and 772.

"Heating-Up Time and Energy Losses of Furnaces", by V. Paschkis. Semi-Annual Meeting of A.S.M.E., Pittsburgh, June 1944.

"Economic Thickness of Thermal Insulation for Intermittent Operation", by C. B. Bradley, C. E. Ernst, and V. Paschkis. *Transactions* of A.S.M.E., V. 67, 1945, p. 93.

"Industrial Electric Furnaces & Appliances", V. I, by V. Paschkis. Interscience Publishing Co., 1945.

"A Thermal Engineer's View of an Arc Furnace", by V. Paschkis. Electrochemical Society Preprint No. 88-20, 1945; *Transactions* of the Electrochemical Society, V. 88, 1945, p. 151.

"Quenching of Steel Balls and Rings", by V. Paschkis. *Transactions*, A.S.M., V. 37, 1946, p. 216.

"Uniformity Problems in Heat Treating Aluminum Alloys", by V. Paschkis. *Aluminum and Magnesium*, V. 2, 1946, p. 12.

"A Study of Heating-Up of Electric-Resistor Furnaces", by V. Paschkis. *Industrial Heating*, V. 13, 1946, Part I, p. 250; Part II, p. 434.

"Calculation of Salt-Bath Electrodes", by V. Paschkis. *Industrial Heating*, V. 13, 1946, p. 784.

"Temperature Uniformity in Heat Treatment of Coiled Metal", by V. Paschkis and J. A. Doyle. *Wire and Wire Products*, V. 21, 1946, p. 369.

"Temperature Uniformity in Heating-Up Processes", by M. P. Heisler. *Transactions*, A.S.M.E., V. 68, 1946, p. 493.

"Heat Treating Furnaces in Foundry Work", V. Paschkis. *American Foundryman*, V. 10, 1946, p. 81.

"Temperature Charts for Induction and Constant Temperature Heating", by M. P. Heisler. *Transactions*, A.S.M.E., V. 69, 1947, p. 227.

"Temperature Control Problems", by V. Paschkis. A.A.A.S. Conference at Gibson Island, Aug. 1946.

"Cooling and Heating Rates of Plates, Cylinders and Spheres", by V. Paschkis. *Welding Journal (Research Supplement)*, Sept. 1946, p. 497-s.

"Thermal Properties of Laminated Materials and Their Significance for Uniform Heating", by V. Paschkis and J. L. Finck. Paper No. 46-F-6, A.S.M.E., 1946.

"Heat Problems in the Steel Industry", by V. Paschkis. *Iron & Steel Engineer*, V. 24, 1947, p. 83.

"Theoretical Thermal Studies of Steel Ingot Solidification", by V. Paschkis. *Transactions*, A.S.M., V. 38, 1947, p. 117; reprinted in abstract in *Industrial Heating*, V. 14, 1947, p. 70.

"The Calculation of Nickel-Chromium Resistors in Heat Treating Furnaces", by V. Paschkis. *Industrial Heating*, Part I, V. 13, 1946, p. 1972; Part II, V. 14, 1947, p. 756.

"A New Tool of Heat Flow Research in the Glass Industry", by V. Paschkis. American Ceramic Society Meeting, Atlantic City, April 23, 1947.

"Influence of Properties on Solidification of Metals", by V. Paschkis, Preprint No. 47-55, A.F.A., 1947.

"Studies on Solidification of Castings", by V. Paschkis. Preprint No. 47-55, A.F.A., 1947.

Protective Metallic Coatings From Molten Salts

By Harry R. Hoge*
Mellon Institute
Pittsburgh

A wartime study of methods for producing a uniformly thin yet continuous metallic layer for protective purposes, so thin that fine dimensional tolerances would not be disturbed, led to the use of fused baths of certain metallic salts. One such bath consisted of tin chloride, either pure or diluted with relatively small amounts of ammonium or other chlorides, and — on occasion — having some extra metallic tin dissolved in it. A general description of the action of such baths on steel articles is presented by Mr. Hoge.

DURING the recent war there arose the problem of developing a thin yet highly corrosion resistant coating for small, intricately shaped metal articles. The usual methods of protecting metals from corrosion, such as electroplating, metal spraying, and painting, are often inapplicable where very fine dimensional tolerances must be met. Thus there was defined the problem of finding a protective coating less than 0.001 in. thick.

It was first thought that vapor coatings could provide the answer to the problem, but the difficulties connected with producing a sound, even coating thereby proved to be too numerous. It will be remembered, however, that in most vapor coatings the reaction takes place electromotively. One factor which determines the rate at which a salt vapor will deposit metal upon another metal is the concentration of metal ion in the vapor. Any increase, therefore, in the number of available metal ions present in a plating process will speed up the process and also increase the probability of obtaining a uniform coating. In order to approach these conditions it was decided to use molten rather than vaporized salts. As a result it was found that if a metal such as iron is dipped in a molten salt such as stannous chloride the surface metal of the sample will be replaced by the metal of the salt, provided the metal of the salt is in the correct position in the electromotive series, or that the cation has more affinity for the metal of the sample than it has for the anion.

A literature survey revealed that molten salts had been used before in several different ways. M. A. Miller, in his U. S. patents 2,299,164 to 168 and 2,321,309 employed molten inorganic salt mixtures as an aid for brazing aluminum and magnesium and their alloys. E. H. E. Johnason (British patent 418,466 of 1934) utilized molten metal halides for metallizing and soldering aluminum and its alloys. Other U. S. patents† indicate that molten salts have been used for fluxes, brazing, welding, and soldering, but the present author is not aware of any inventions relating to the application of molten salts for the production of corrosion resistant coatings on base metals.

Defining the cementation process as the process of plating one metal with another from molten salts, there are two ways in which this cementation

*Multiple fellowship on watch technology sustained at Mellon Institute by the Elgin National Watch Co., Elgin, Ill. Thanks are due to the sponsor for permission to publish. Special acknowledgment is also made to Frederick N. Rhines, Assoc. Prof. of Metallurgy, Carnegie Institute of Technology, for suggestions and encouragement.

†P. W. Noble and A. R. Powell, 2,169,659; J. M. Michel, 2,171,041; J. F. Howarth, 2,179,258; S. B. Wilson, 2,216,928; O. Horowitz, 2,243,424; J. S. Streicher, 2,267,762; and C. A. Corey, 2,327,958.

process may be carried out, although one of them is only a slight modification of the other:

Method A — A salt mix of desired composition is brought to the desired temperature, then the objects to be plated are dipped in the salt bath. When the articles have been in the salt bath for the correct length of time they are removed, quenched in water, and dried.

Fig. 1 — Nails and Tap That Had Rusted a Week in a Laboratory Sink; One End of Each Was Then Dipped in Molten Stannous Chloride and Satisfactorily "Tinned"

Method B — The objects to be plated are first heated to a bright red heat and then quenched in the molten salt bath. The rest of the procedure is the same as in Method A.

In general, the uses for each process are as follows: Method A permits greater control of the coating thickness and is not likely to change the microstructure of the metal being plated. Method B is very fast — for example, good coatings have been obtained in 1 to 3 sec. — and the bath temperature does not need to be as closely controlled as it does in Method A.

Salt Baths

Salt baths may contain one or more salts depending upon the coating desired, the condition of the surface of the material being coated, the rate at which the coating is to be effected, and the temperature at which the protective coating is to be applied.

First, consider the kind of coating which is to be aimed for. Coatings may be bright or dull, single metals or alloys, thin or thick, or combinations thereof. For example, a bright alloy coating may be deposited on iron by dipping the sample in a mixture of 90% stannous chloride with 10% cadmium chloride. (This coating is also an example of an alloy coating.) A dull coating may be prepared on iron objects if the bath temperature is lowered, the time of immersion is shortened, or certain impurities are added to the salt bath.

Very thin coatings have been produced by Method B as well as by short-time treatment using Method A, as indicated by the lines in Fig. 2. It has also been found that very thick coatings may be obtained by using a salt bath which has dissolved some of the metal.

Secondly, the condition of the surface of the material being plated determines the time necessary to produce a given coating. It may be said, however, that no precleaning of the surface to be coated is necessary where molten salt baths are used for plating, although, if the surface is relatively clean, the cementation process proceeds at a faster rate and a better coating is assured. The following observation may be cited to illustrate how bad a surface may be and yet be platable: Nails were left in a laboratory sink for one week where water and chemicals were splashed on them every day. At the end of the week the nails were removed and dipped in molten stannous chloride.

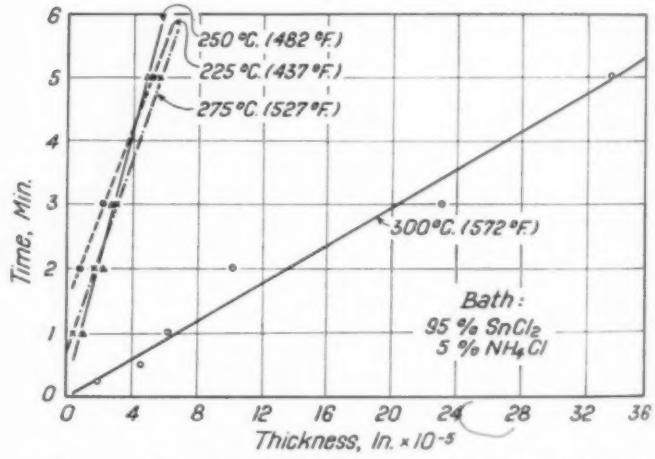


Fig. 2 — Variation of Thickness of Tin Coating on Steel With Time, Temperature Being Constant

Figure 1 shows how the tin-plated part of the nails compares with the still rusted portions of them. At another time, two pieces of cold rolled rod were heated in a resistance furnace to 1000° C. (1830° F.). One was air cooled and the other was furnace cooled. The air cooled rod was covered with a tough oxide skin while the furnace cooled rod had a flaky oxide coating. Both of the rods were dipped in molten stannous chloride and the oxides were removed from both and their surfaces were "tinned".

Thirdly, the composition of the salt bath may be changed in order to speed up or slow down the plating rate. For example, the rate at which tin will plate on iron from molten tin chloride is quite fast, so it is often desirable to slow down the reaction. One way to do this is to add 5 to 25% ammonium chloride to the tin chloride bath; the ammonium chloride decreases the number of available tin ions in the bath and therefore slows down the reaction. Some years ago the author found an approximate relation of interest here, namely, that the thickness of coating obtained is inversely proportional to the square of the percentage of diluting agent present in the mix.

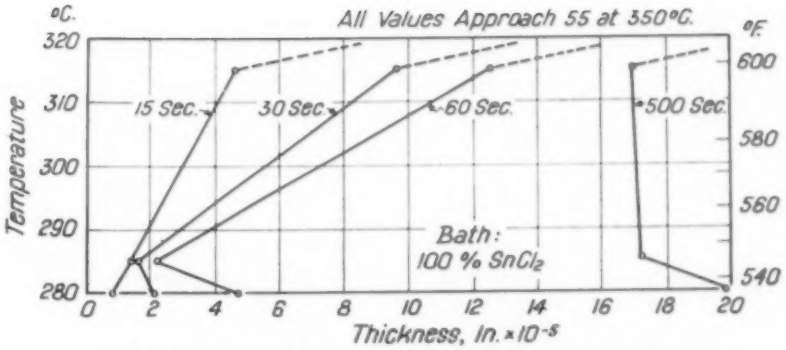


Fig. 4 — Variation of Thickness of Tin Coating on Steel With Temperature, in a Bath of 100% Stannous Chloride, Time Being Constant

Other salts may be added to a plating bath to serve as fluxes; for example, calcium fluoride may be added to stannous chloride to help remove or dissolve metal oxides from the surface of the material being plated, thus insuring a more uniform coating.

Fourthly, for practical reasons it is best that the temperature of the salt bath be as close to the melting point of the metal being plated as possible.

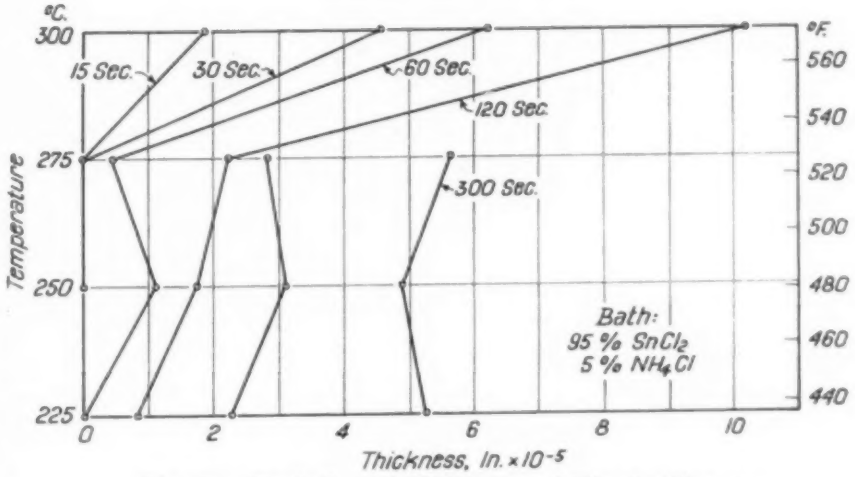


Fig. 3 — Variation of Thickness of Tin Coating on Steel With Temperature, Time Being Constant

If the temperature of the bath is too high, the plated metal will flow from the object on which it has been deposited. If the salt bath temperature is below the melting point of the metal being plated, a spongy coating will be produced which must be annealed before a solid, even layer is obtained.

Furthermore, the operating temperature of a salt bath to be used for plating depends to a large extent upon the fluidity of the mix. A very fluid bath will wet all parts of the objects being plated at approximately the same time. If one is dealing with very small parts, as shown in Fig. 7, this property is very important; for, if the whole surface of the object is not wet at the same time, the coatings will be too thick in some spots and too thin in others. There are, then, two general ways in which increased fluidity may be obtained: First, obviously, one can raise the temperature of the salt bath; this method is effective but often undesirable. Second, there can be added other salts which lower the melting point of the bath, and so render it more fluid at a given temperature than the original. To illustrate, if 10% ammonium chloride is added to tin chloride, the freezing point is depressed 27° C., but the increased fluidity of tin chloride plus 10% ammonium chloride at 250° C. (480° F.), for example, is much greater than the fluidity of pure tin chloride at 277° C. It should be noted, however, that increased fluidity does not necessarily mean an increased rate of plating.

Coating Thickness

The thickness of the coatings has been measured by three methods:

1. Calculation from weight differences.
2. Measurement with a Magne-Gage.
3. Direct measurement of a cross section with a metallographic microscope.

It would seem that one of the easiest methods to determine the thickness of a coating of a regularly shaped object would be to weigh the sample before and after it had been plated, and from the

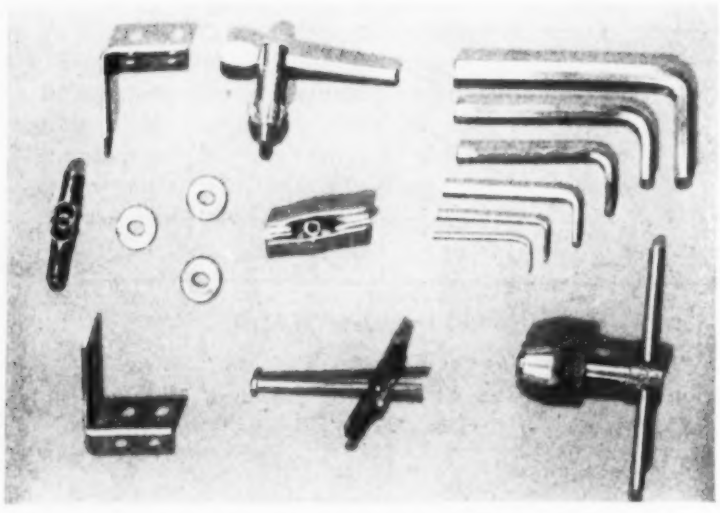


Fig. 5 — Small Tools and Items of Hardware "Tinned" in Molten Stannous Chloride

increase in weight calculate the amount of metal which had been deposited, but this method offers the following difficulties: The weight increase of the sample, if any, is not a direct measure of the metal which has been deposited, because, for every mole of metal deposited, there is a mole of base metal removed. When tin is being plated onto iron from tin chloride, the only reason there is an increase in weight at all is because the atomic weight of tin is 2.12 times the atomic weight of iron, and even so, it has been found that at times the sample is lighter after it is plated than it was before. Since this only happens at relatively higher temperatures, it has been assumed that some of the tin which had been deposited had run off, thus leaving the sample lighter by an amount equal to the weight of the iron which had been removed.

Following is a formula to determine the thickness of a coating calculated for the plating of tin on iron, but the constant term will change if either the plated metal or the base metal is different.

$$t = \frac{0.0157\ W}{A},$$

where t is the thickness of coating, W is the increase of weight of the sample, and A is the total area of the sample.

Tin-plated steel samples were examined with a General Electric Type B magnetic thickness gage to determine the thickness of the plating. The plate was found to be 0.1 to 0.3 mil, which is of the same order of magnitude as the values obtained by calculation.

By direct measurement with a metallographic microscope, the average thickness of the tin coatings was 1.3 mil; however, these samples had a much thicker coating than any of the other specimens which were observed. It would seem, then, that the average coating thickness, judging from the three methods given above, is probably 0.0001 to 0.0005 in. (0.1 to 0.5 mil).

The principal factors which determine the thickness of a coating obtained from a molten salt bath are as follows: *(a)* Time in the salt bath, *(b)* temperature of the bath, *(c)* initial temperature of the specimen, and *(d)* composition of the bath. It may be seen from Fig. 2 that at times a nearly straight-line relationship exists in the plot of time versus thickness. Theoretically, there should be a maximum thickness which could be obtained. Actually, this is not the case, probably because of various diffusion processes which are going on at the same time. Also, it can be seen from Fig. 2, 3 and 4 that, if the bath temperature is below 300° C. (570° F.), the time at

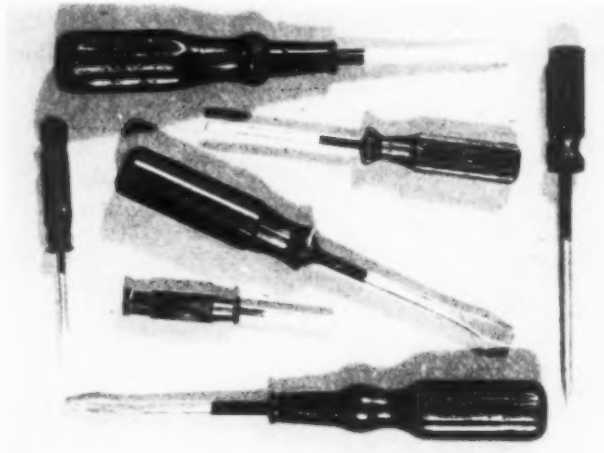


Fig. 6 — Ends of Screwdrivers After Tinning and Exposure to Corrosive Conditions in Laboratory

temperature is the controlling factor in obtaining any desired coating thickness; however, the *temperature* is the controlling factor above 300° C.

The temperature 300° C. (570° F.) is an average temperature. In Fig. 3 the change in rate begins below 300° C., while in Fig. 4 the change begins above 300° C.; but in all experiments the bath temperature could not be controlled very accurately with the equipment available. Factor *(d)*, composition of the bath, is somewhat responsible for shifting the temperature at which the rate of plating changes. In Fig. 4, the bath contained only stannous chloride, while in Fig. 3 it consisted

of 95% stannous chloride plus 5% ammonium chloride. As noted above, the ammonium chloride not only decreases the melting point of the stannous chloride but also increases its fluidity. The increased fluidity caused by the 5% ammonium chloride does not compensate the dilution effect, but changes the temperature at which the "temperature of bath" becomes the controlling factor.

Factor *(c)*, the initial temperature of the specimen, must also be considered if one wishes to determine the time necessary to produce a certain thickness of coating. If the object to be plated is at room temperature upon entering the salt bath, there is a certain time lag in which it is being heated to where the plating reaction can proceed at an appreciable rate. It can be seen from Fig. 2 that the higher the bath temperature the shorter the time to obtain a measurable coating. An extreme case is the Method B mentioned previously, wherein the specimen enters the bath red hot and a good coating may be obtained in 1 sec.

Contamination of Salt Bath

As the number of iron articles that are plated in a molten salt bath is increased, the amount of iron in the salt bath is increased. In order to determine the concentration of iron necessary in a salt bath to stop the plating process, two stannous chloride baths were made up containing 5 and 10% ferrous chloride, respectively. Stannous chloride with 5% ferrous chloride bath plated out tin very well, but the bath was quite foamy so that it would not be very useful. The bath containing 10% ferrous chloride was too volatile to use; also there was very little tin plated from it. It would seem that in practice "tinning" may be carried out in a stannous chloride bath as long as the iron content is less than 5%.

Because the iron concentration in a cementation bath is built up and not useful as a salt bath for cementation if the iron concentration is greater than 5%, it is necessary that the iron be removed at the same rate it is taken into solution. To learn about the removal of iron, graphite electrodes were placed in a molten salt bath and a low current was applied. After the electrodes had been removed, the salt bath was analyzed and it was found that the iron concentration was lower. Therefore, it has been inferred that iron may be removed by electrolysis. It is plain, of course, that exact operating conditions would have to be found for a standard plating bath.

The effects of the presence of iron in a cementation bath may also be compensated by the addition of a pure metal to the bath. For example, tin may be added to a tin chloride bath to reduce the harmful effects of the iron.

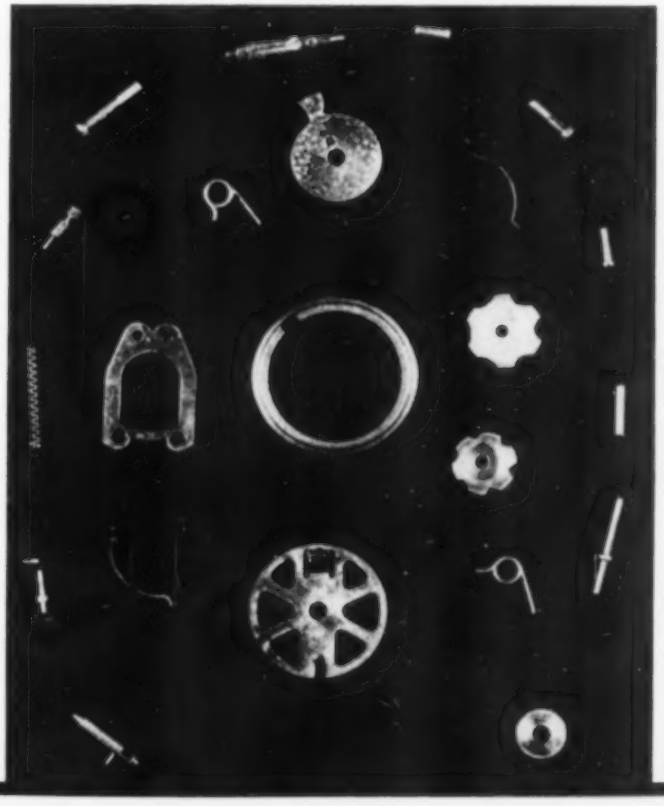
Uses for the Process

Cementation with molten salts is a convenient and easy method for plating small, intricately shaped metal objects. Figures 1, 5 and 6 illustrate typical uses for the process around the laboratory. All the objects shown were rusted and corroded from the laboratory atmosphere and activity, but the cementation process removed all corrosion products and served to protect the articles from further corrosion. Such things as the Allen wrenches and the Jacobs' chuck keys in Fig. 5 are not only protected against corrosion but are also improved in appearance. Figure 7 shows some other types of objects which have been plated in this laboratory.

Another use for molten salt baths is the reduction of metal salts to obtain the pure metal. For example, a cheap metal such as zinc, which is also high in the electromotive series, may be used to reduce tin from tin chloride or cadmium from cadmium chloride. The method is not only useful for obtaining certain metals from their salts but the process occurs almost instantaneously.

Other uses are not in the field of corrosion protection but may be mentioned again. For example, copper may be cleaned quickly and completely in molten cadmium chloride. Aluminum and magnesium and their alloys may be soldered and metallized with molten salts and practically any difficult tinning job, such as for soldering, may be done with molten salts.

Fig. 7 — Small Steel Parts After "Tinning"



A Systematic Scheme for Identifying Corrosion Resistant Metals

By Chester J. Zeeh
University of Chicago

METALLURGISTS are always busy men. They often do not have time to wait for chemists to complete analyses of unknown metals. Frequently the job does not warrant sampling and chemical analysis. However, the importance of segregating accidentally mixed alloys forces metallurgists to find schemes for quick identification. The profusion of methods available, however, tends to defeat the very purpose for which they were devised — that of saving time. Most schemes for qualitative identification of unknown metals are not systematic; therefore, it is necessary to complete many "quick" tests to determine what class or type a metal properly belongs in, and then proceed to pin it down to some one member of that type.

The chart appearing as the data sheet, page 824-B, is the result of library and laboratory research by the author on the subject of identifying metals qualitatively. A few innovations have been incorporated in the data sheet, made possible by a simple instrument called the electrograph.

The electrograph was invented by A. Glazunow and described in French and German chemical literature in 1929 and 1930. Many publications have mentioned its use. A complete description was printed in *Metal Progress* for December, 1942, in an article by Messrs. Hunter, Churchill and Mears of Aluminum Co. of America's research laboratories. H. W. Hermanse has also described the use of the electrograph for analyzing metals in *Bell Laboratories Record*, V. 18, 1940, p. 269. F. Fiegl has since incorporated the electrographic nickel spot test as a routine method in his book entitled "Spot Tests", published by Academic Press in 1939.

In brief, electrographic methods are those whereby minute quantities of surface materials

Electrographic Tests for Metals

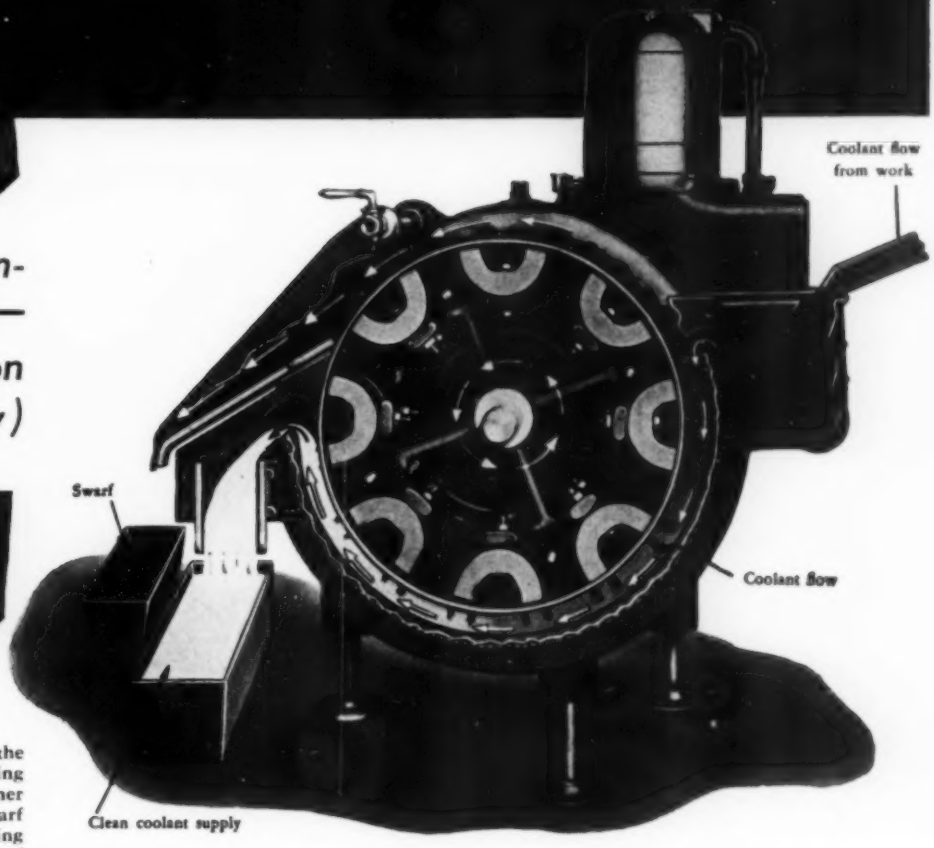
Element	Electrolyte	Developer	Color	Interference
Aluminum	5% K_2SO_4	Aurin tricarboxylic acid, 1%	Red	Beryllium
Antimony	5% K_2SO_4	First 3% H_2O_2, then 1% rhodamine B	Violet	None
Cadmium	5% NH_4Cl	Saturated solution diphenylcarbazide in C_2H_5OH	Blue	Cobalt
Cobalt	5% NH_4Cl	1% dithioxyamide in C_2H_5OH	Brown	None
Columbium	5% oxalic acid	Saturated solution of tannin	Red	
Magnesium	5% K_2SO_4	0.05% p-nitro-benzene-azo-resorcinol	Blue	None
Manganese	5% KNO_3	1% tetramethyldiamino diphenylmethane	Blue	Excess chromium
Molybdenum	5% KCl	First 1% $SnCl_2$, then 5% KCNS	Red	None
	5% HCl	1% phenylhydrazine in acetic acid	Red	None
Nickel	5% KCl	Saturated solution dimethylglyoxime in c.p. alcohol	Red	
Silver	5% KNO_3	5% solution potassium chromate in acetic acid	Brick red	
Tin	5 *N* HCl	Saturated solution cacotheline	Violet	None
	5% HCl	0.01% diazine green	Red	
Titanium	5% H_2SO_4	5% solution of chromotropic acid	Red-brown	
	5% KCl	Saturated solution pyrocatechal containing 1% H_2SO_4	Yellow-red flecks	
Tungsten	5% HCl	0.01% rhodamine B	Bluish-red	Antimony
Vanadium	5% KNO_3	0.01% phenylhydrazine	Greenish-blue	Molybdenum

Cutting Oils Re-claimed Automatically...

with the help of...

ALNICO MAGNETS

(Aluminum-NICKEL—Cobalt—Iron Alloy)



BARNESDRIL AUTOMATIC MAGNETIC COOLANT SEPARATOR . . . pictured to show operation. Coolant from the work flows, as pictured, around a revolving drum that carries Alnico magnets on its inner face. On its outer face, the magnetic swarf fastens endwise over each magnet. Traveling with the drum toward a scraper, the swarf fine-combs most of the other entrained non-magnetic particles from the coolant. Standard sizes handle 5, 10, 20, 40 or 100 gal. per min.

Here's an open view of a separator that completely frees machine operators from the task of keeping coolants clean.

Fully automatic, this type reclaims as much as 100 gallons of oil per minute.

Developed and produced by Barnes Drill Co. of Rockford, Ill., the equipment incorporates a series of Alnico permanent magnets containing 20 per cent Nickel, which contribute fundamentally to the unique efficiency of this separator.

The exceptionally high magnetic properties of Alnico, an aluminum-Nickel-cobalt-iron alloy, permit designs that were technically impossible with older materials. Compared with the latter, Alnico reduces space and weight requirements to practical limits.

Nickel, an essential element in Alnico, also improves hundreds of other alloys for applications in the machine tool industry.

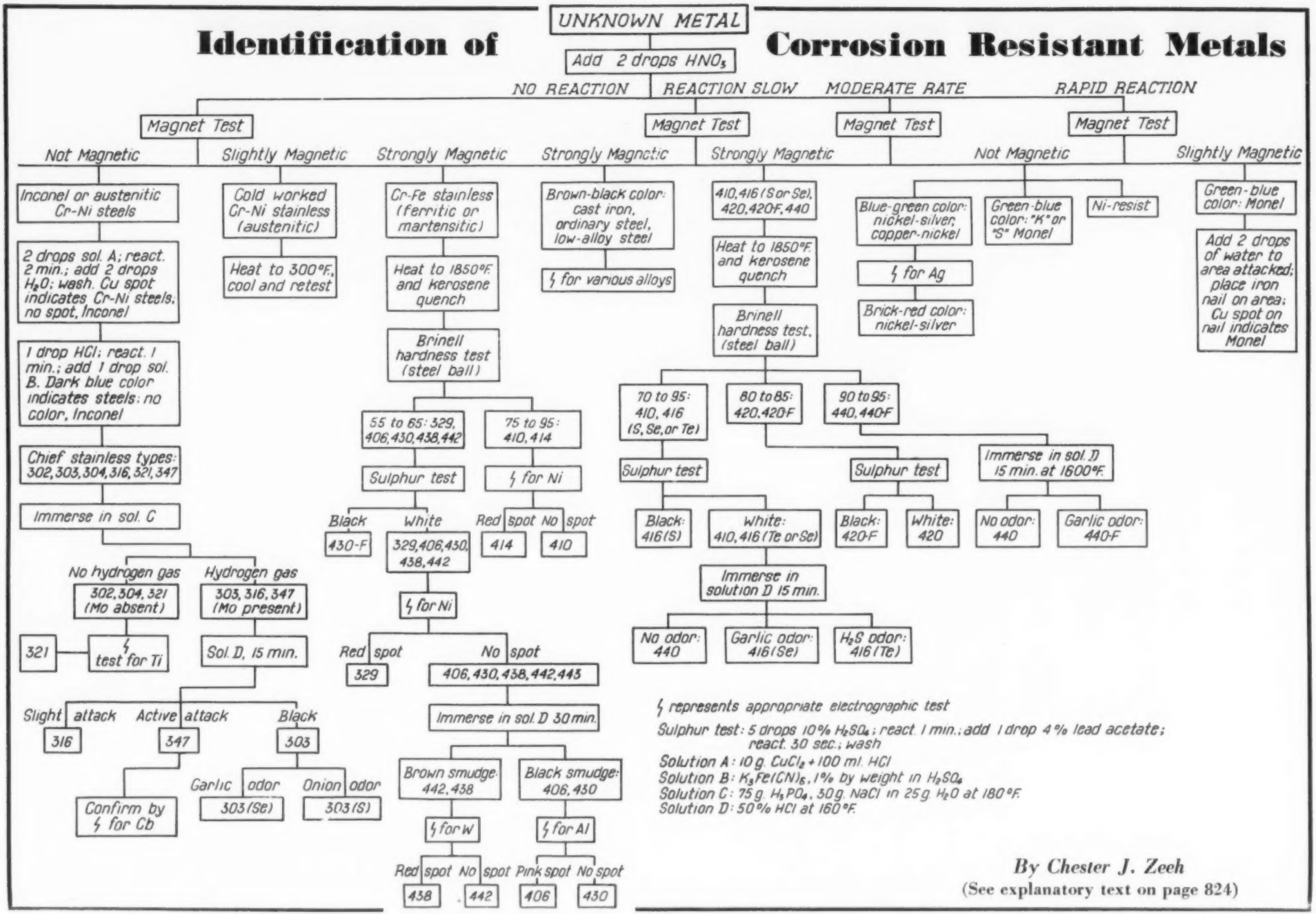
We invite consultation on the use of Nickel or Nickel alloys in your products or equipment.

EMBLEM OF INCO SERVICE
TRADE MARK

Over the years, International Nickel has accumulated a fund of useful information on the selection, fabrication, treatment and performance of engineering alloy steels, stainless steels, cast irons, brasses, bronzes and other alloys containing Nickel. This information is yours for the asking. Write for "List A" of available publications.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Identification of Corrosion Resistant Metals



for represents appropriate electrographic test

Sulphur test: 5 drops 10% H_2SO_4; react 1 min.; add 1 drop 4% lead acetate; react. 30 sec.; wash

Solution A: 10 g. $CuCl_2$ + 100 ml. HCl

Solution B: $K_3Fe(CN)_6$, 1% by weight in H_2SO_4

Solution C: 75 g. H_3PO_4, 30 g. NaCl in 25 g. H_2O at 180°F.

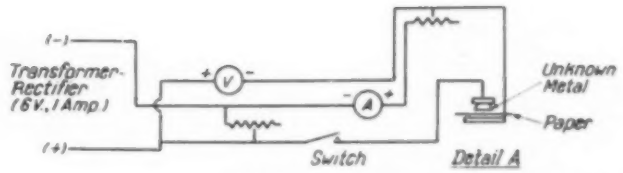
Solution D: 50% HCl at 160°F.

By Chester J. Zeeh

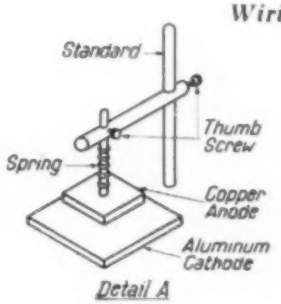
(See explanatory text on page 824)

are removed by applied potential from the metal being analyzed. These substances are retained on imbibition paper,* and subsequently identified by suitable spot developers. The reagents used for spot developers are usually the same as those used for colorimetric analyses. A chart of the electrolyte and developer recommended for the principal metals is given at the bottom of page 824.

The construction of the electrograph and the wiring diagram is shown in the sketch. It is not difficult to use. The metal to be analyzed must be ground flat for good contact with the gelatin-coated paper, and thoroughly degreased by acetone. This specimen is then placed on the imbibition paper, previously saturated in the proper electrolyte. The thumbscrew on the post supporting the copper anode is then loosened and the spring clamps the specimen and paper rigidly in place. Then the current is allowed to pass until the amperage falls off. The specimen is removed, and the paper is washed in distilled water and developed in the proper reagent.



Wiring Diagram and Sketch of Electrograph



The electrographic methods as described also can be used for detecting and determining the nature of inclusions and porosities in steels and other alloys. When used for this purpose the operator must determine whether or not the electrolyte reaches up into the cavities and recesses; positive electrical contact is important, for such cavities and recesses are often relatively deep.

Correspondence and Foreign Notes

Can Hardenability Bands Be Narrower?

TULSA, OKLA.

To the Readers of METAL PROGRESS:

President Boegehold of the is reported by the Editor of *Metal Progress* ("Critical Points", page 426 of the March issue) to favor narrower hardenability bands for the "H" steels. His stand is doubly worthy of attention because he was a member of the group that originally approved the present specifications.

It has also been the writer's thought that the existing hardenability bands could be somewhat narrowed without upsetting the economic apple-cart. For example, let us consider a common versatile alloy steel such as A.I.S.I. 4140. After 4/16 in. is passed on the "tentative hardenability band" (and I use the term advisedly because it has been unchanged since 1944 when it was tentatively accepted) the band widens from 10 Rockwell points to 20. Actually all of this occurs from 4/16 to 14/16 in. on the end-quench bar. That almost amounts to going from the minimum to the maximum of every element in the standard chemistry range.

Unfortunately, the writer has had no experience in openhearth melting, his work being confined solely to basic electric. However, it seems with the excellent work that has been done in openhearth practice that extensive latitude as to composition and hardenability has been granted the steelmaker. (As a steel purchaser I am now on the other side of the fence!)

Assuming deoxidation methods to be fairly uniform in any given melting shop, let us see what might be expected by calculating certain variables in analysis using the standard A.I.S.I. A4140 range. (For comparison the 4140H limits are also quoted in the table immediately following.)

*A gelatin-coated paper is on the market as "Eastman's Imbibition Paper", which is quite satisfactory.

Chemical Ranges for 4140

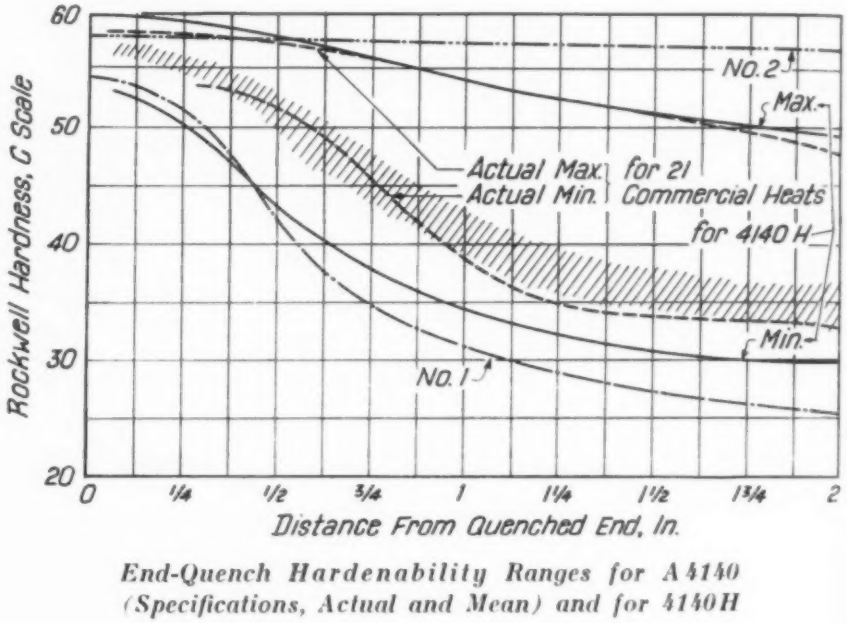
	A4140		4140H
	Specification	21 Heats	
Carbon	0.38 to 0.43	0.38 to 0.415	0.37 to 0.45
Manganese	0.75 to 1.00	0.83 to 1.00	0.70 to 1.05
Silicon	0.20 to 0.35	0.21 to 0.35	0.20 to 0.35
Chromium	0.80 to 1.10	0.86 to 1.04	0.80 to 1.15
Molybdenum	0.15 to 0.25	0.18 to 0.23	0.15 to 0.25

Curve No. 1 represents conditions for a steel having all five elements simultaneously at the minimum allowable for A4140, No. 2 at maximum. Similar curves for 4140H are shown. The shaded band is the locus of four curves as follows: *(a)* 0.38% carbon and the other elements at average of permissible range in A4140, *(b)* 0.75% manganese and the other elements at average of range, *(c)* 0.80% chromium and the others average as before, *(d)* 0.15% molybdenum and the others average. Thus, in all of the four, the maximum alloy content was at or below the average in the range permissible.

Using these four theoretical curves it can be seen that the bottom of their band is 4 to 6 Rockwell points higher than the bottom of the 4140H band at distances of 4/16 to 20/16 in. on the end-quench specimen. To somewhat substantiate this idea that minimum hardenability now allowable is too low, the dotted lines on the diagram are offered. They are constructed from 21 openhearth heats, using the Jominy results furnished by the steel producer. From the analysis range of these 21 heats, listed above, it is apparent that the steel producer has attempted to hold to an average chemistry, and with this control has had no difficulty in narrowing the hardenability band — at least in raising the low levels.

It is also worthy of note that the problems offered by wide hardenability limits are not confined to industries employing the continuous type of heat treating furnaces. Hardenability bands also make it very difficult to meet desired physical properties when higher carbon content results in excessive rejects due to cracking. This is exemplified in a part with certain hardness requirements which can be met with 0.38 to 0.43% carbon and a minimum curve 15 Rockwell points below the present maximum of 4140H, but for which the present tentative bands necessitate a 4145H steel of 0.50% carbon max. This carbon unfortunately has proved to cause excessive quench cracking failure, as previously pointed out.

In the same discussion described by the Editor, Harry McQuaid made some true statements about nonuniform steel. A certain amount of nonuniformity arises, not through melting practices nor procedures, but through the natural mechanics of solidification. However, this segregation should be mitigated by proper soaking at forging or rolling temperatures. Consequently, it seems that the lion's share of the reasons for the present wide hardenability bands would be off-analysis (from average chemistry) or variable deoxidation practices.



End-Quench Hardenability Ranges for A4140 (Specifications, Actual and Mean) and for 4140H

The writer would like it understood that he is appreciative of the quirks of melting and melting furnaces, but realizes too that "the squeaking wheel gets the grease". If demands were not made by purchasers, conditions would change much more slowly.

L. W. Cashdollar
Chief Metallurgist
Hinderliter Tool Co.

Low-Nitrogen Steel

In the interesting and important article by Yves Dardel on "Manufacture of Basic Steel Low in Nitrogen" (*Metal Progress*, August 1947), an unfortunate error was made. At the head of the last paragraph (page 256) are the words "Nitrogen is bound to be higher in normal basic (Thomas)

steel than in the normal acid steel made in America, since the most of the nitrogen is absorbed in the after-blow which eliminates phosphorus from the basic steel." M. Dardel writes that experiments show that acid bessemer steel contains as much nitrogen as Thomas steel. This statement is also confirmed by the theory developed by him. In Thomas steel the amount of carbon and phosphorus slows down the nitrogen absorption to some extent. In acid steel, where no phosphorus is present, the experimental absorption curve like that of Fig. 2 (valid for Thomas steel) shows that nitrogen absorption by steel begins earlier.

A Measure of Dispersion of Carbide Spheroids

PARIS, FRANCE

To the Readers of METAL PROGRESS:

I was attracted by the most excellent photographs of lamellar and spheroidized cementite published by C. Patrick Kenyon in *Metal Progress* for February and am emboldened to present my recently developed scheme for the numerical characterization of spheroidite. This is a supplement to my plan for designating the fineness of a lamellar structure, first developed in 1922, adequately explained in O. V. Greene's study of pearlite in rail steel (*Transactions*, A.S.S.T., July 1929, p. 37), and utilized by R. F. Mehl in his chapter in the book on "Hardenability of Alloy Steels".

It is desirable to grade coalesced structures according to the number of globules appearing in unit area of the micrograph. I have proposed the term "dispersion" for this factor. If A is the number per sq.cm. on the actual steel (not magnified), M the number per sq.cm. on the photomicrograph, G the magnification, and N the dispersion, then

$$M = \frac{A}{G^2} = 2^N$$

It will be noted that the dispersion, N, progresses in exponential form, as does the standardized rating for grain size.

In order to establish the ratio between the dispersion, N, and the diameter of the globule, d_g, Jolivet's suggestion has been followed by using, as reference point, the total surface of the globules of cementite in a steel containing 1% of carbon, that is, with 15% of cementite. Thus,

$$d_g = \sqrt{15} \cdot 2^{-\frac{N}{2}}$$

Figure 1 gives the dispersion, the number, and the diameter of globules for dispersions 1 to 10, with particles of 2700 to 150 μμ. Globules with a dispersion between 10 and 11, hence 120 to 85 μμ, are

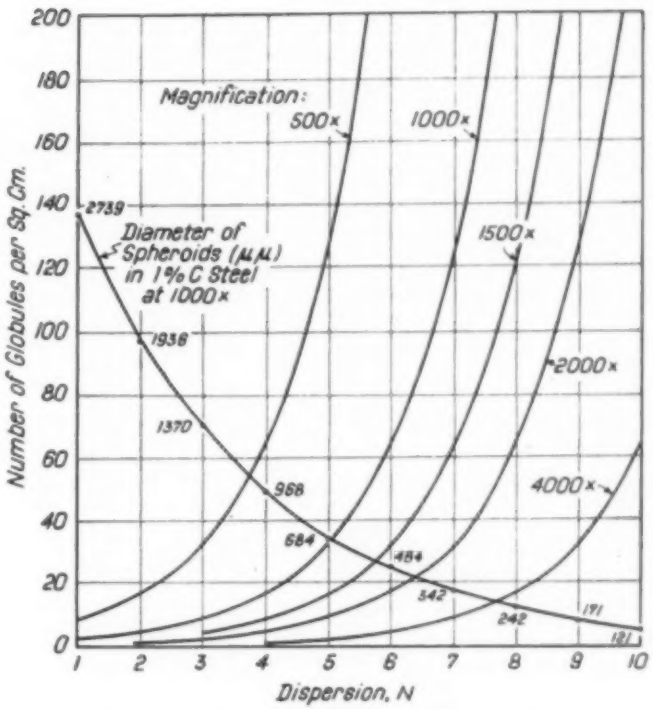


Fig. 1 — Relation Between Number of Cementite Globules Per Sq.Cm. Appearing on Micros at Various Enlargements and Their "Dispersion", and Diameter of Spheroids in μμ at 1000 × in 1% C Steel at Various Dispersions

still discernible by good immersion systems. Ultramicroscopic aggregates will fill the dispersions between 10 and 25; this last one is the molecular dispersion. Figure 1 also shows the diameter of the cementite globules in a 1% carbon steel, under various dispersions.

In agreement with Bain and Mehl we consider that the state of agglomeration of cementite is appreciably the same in lower bainite and in slightly tempered martensite of hardness C-60. In small dispersions, for systems with Brinell hardness of about 140, the dispersion is 2, and for 190 Brinell it is 5.

In common pearlites, of spacings of the order of 300 μμ, the corresponding dispersion will be about 9, and the cementite lamella divides into nearly 1000 globules. In Mr. Kenyon's photographs the spacing seems to be nearer 350 μμ, and the dispersion of the corresponding coalesced structure in his Fig. 2 is about 7. According to our scheme of classifying carbides these fall into the class of "fine" or "hardenability carbides", and pass readily into solution. On the other hand, medium carbides, of dispersions from 3 to 5, are not so readily dissolved and, like inclusions, become promoters of crystallization.

N. T. BELAIEW

Mathematical Analyses of Metallurgical Data

NEW YORK CITY

To the Readers of METAL PROGRESS:

I wish to raise my voice on the subject of "mathematics" as applied to metallurgical investigations, and I put the word in quotations designedly. I realize, of course, that a symbolic summary of a systematic set of accurate experiments by means of a mathematical relationship is of value, not only as a shorthand method of expression but also as a means of estimating intermediate and slightly extrapolated values. However, it is attacking the problem from the wrong end if (as Mr. Liedholm did in the February issue) a formula like the Gompertz equation is chosen for no other reason than that — by properly selecting the exponents — a curve can be computed that approximates the location of the observed values.

Now let us see if there is not a more logical approach to the systematic evaluation of the cooling time of Jominy bars to half-temperature (the matter which Mr. Liedholm was discussing). The cooling process of a Jominy test piece consists of *three* phenomena, essentially independent, although interfering with one another in a very complicated manner:

1. The axial cooling by the quenching stream striking the end.

2. Radiation of heat from the cylindrical surface.

3. Convection.

Now it is certain that no formula with a single variable member can account for a tripartite process of this kind. It must (at least) be a three-member equation, the three members connected by a plus or a minus sign. Even though the last of these factors (convection) may be neglected because of the moderate experimental precision, there would still be two members of the equation.

If we use Mr. Liedholm's data and figure the average velocity of cooling at the various distances from the end of the Jominy bar we get a series of values that plot on a smooth curve (*A* on the adjoining graph) which looks like a hyperbola that approaches asymptotically the value of about 6.5×10^{-3} (horizontal line *C*). The explanation is simple. The further we go along the length of the test bar the lower the axial speed of cooling becomes, and at some by no means infinite distance it becomes quite imperceptible in comparison to the speed of cooling by radiation and convection. (The latter two also have a certain limit which is approached asymptotically.)

What this amounts to is that the actual cooling velocity curve is the algebraic sum of two curves, one for the artificial cooling by end quenching, and one for the natural cooling by radiation. Both curves approximate asymptotic hyperbolas. But no ordinary hyperbola would fit the curve — which is to be expected, for too many things interfere with the cooling process. A much better approximation for the main process is the exponential hyperbola

$$y = A + \frac{Br^x}{C + x}$$

Mr. Liedholm's data are susceptible to an analysis, therefore, wherein the velocity of temperature drop due to end quenching is approximately

$$V = \frac{84.5 \cdot 0.81^x}{0.015 + x}$$

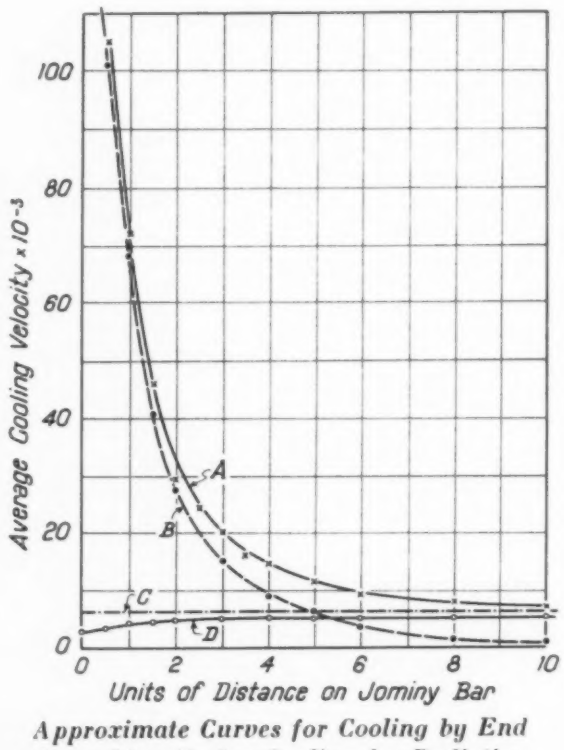
which is plotted as curve *B, and* the velocity of temperature drop due to radiation

$$v = 6.5 - \frac{6}{x + 1.7}$$

which is plotted as curve *D*.

These equations fit the observations quite well except at position ⅛ in. from the cooled end. Yet one could hardly maintain that Mr. Liedholm's figures of 9.5 sec. for the time of cooling to half-temperature from 1700° F. and ⅛ in. (0.125 in.) for the distance are precise. (My formula calls for 9.5 sec. at 0.140 in. rather than 0.125 in.)

It would appear, therefore, that the cooling



Approximate Curves for Cooling by End Quenching B, for Cooling by Radiation D, and for the Combined Effect A

process might just as well be represented by the summation of two equations representing essentially hyperbolic processes. I would not go so far as to say that the hyperbolic formulas account for *all* the factors involved. The true situation might be far more complicated. But this analysis, rather than a twisting of the dubious Gompertz equation, has the advantage that the physical meaning is quite clear and it produces something that is logically correct.

MICHAEL G. CORSON
Metallurgical and Chemical Consultant

Coalescing Anneals

PARIS, FRANCE

To the Readers of METAL PROGRESS:

It is well known that the machinability of medium and high carbon steels depends upon the state of cementite agglomeration. Very frequently it is necessary to "spheroidize" the structure — change the cementite into globular particles rather than lamellar. The physical principles underlying this heat treatment are not so well known; consequently unsatisfactory results sometimes follow even lengthy heating cycles.

Coalescence or spheroidization is the result of capillary forces which have a double effect: *(a)* To round out the particles, and *(b)* to agglutinate and unite them. The first effect may be compared to the formation of lead bullets in a shot tower; the second to the growth of hail stones. The results of a spheroidizing anneal will depend, as does all heat treatment, on the initial condition of the alloy, and the time-temperature cycles.

Coalescence will take place more rapidly and more readily if the initial structure is fine and granular rather than coarse or lamellar. Thus, with the same heat treatment, the coalescence and resulting softening will be more pronounced if the original structure is "sorbitic" (that is, granular and ultrafine tempered martensite) than if it is "troostitic" (ultrafine but lamellar), and will be very difficult if the structure is lamellar pearlite or coarse bainite. This may readily be proved by reheating a Jominy test bar made of steel of such a degree of hardenability that after end-quenching and low tempering it will contain all gradations in structure between fine granulite and relatively coarse pearlite.

Therefore by tempering and low annealing (heating below the Ac_1 point) the carbides tend to coalesce and this will take place more rapidly as the temperature is raised. It is obviously better to work with steels that have been rapidly cooled or even quenched, and heat to as high a temperature and for as long a time as possible.

If the temperature is raised slightly above Ac_1, the cementite coalesces more rapidly, and at the same time it begins to dissipate by the disappearance of the finest particles — solution into the austenite. To retain some cementite particles, to act as nucleation centers of spheroids on later cooling, it is necessary to avoid overheating; the maximum temperature of a spheroidizing anneal cannot be very far above Ac_1.

Assume now we have such a hot piece of steel wherein many undissolved carbide particles exist in the austenite. On cooling through A_1 this austenite starts to transform and the resulting structures will (as is well known) depend on the temperature of transformation — that is, its degree of supercooling. The existing cementite particles will grow by accumulation of Fe_3C from their immediate surroundings; what happens to the cementite in solution that does not so deposit is a matter of practical importance.

To obtain globular cementite from this austenite it must transform at a temperature where the rate of crystalline growth is low, either by slight supercooling in a zone above Ar′ where globular cementite is obtained directly, or in supercooling to a zone below Ar′ where very fine granular structures are obtained (granulite).

The possibility of such supercooling depends mainly on the number of residual nuclei and the austenitic grain size. (Both of these are a function of the superheating in relationship to Ac_1.) For example, Bain has shown that with two test pieces of the same steel, one coarse-grained and the other fine, the first formed lamellar pearlite at 703° and the other a globular structure at 707°, the larger number of grains being responsible for the transformation at a temperature slightly higher with lower rate of growth.

Coalescence can therefore be obtained by annealing slightly above Ac_1, followed by very slow cooling so that austenite will retain a sufficient quantity of undissolved cementite nuclei and will transform at a rather high temperature. Cooling rate should be very slow because transformation rate is then also very slow, and time will be allowed for the transformation to be completed when the temperature reaches the faster cooling zone where lamellar pearlite is formed. Thus, if an isothermal level can be maintained for the time necessary for complete transformation, the steel can then be rapidly cooled — even quenched — and a perfect result is obtained with a low total annealing time.

If the rate of carbide deposition is too slow for this method of procedure, a thermal level can be reached in a zone below Ar′ so as to obtain a very fine granulite structure, which (as we indi-

cated in a paper with H. Jolivet, *Comptes Rendus*, Vol. 208, 1939, p. 1404) coalesces very rapidly when the steel is reheated to the zone of rapid coalescence immediately below Ac_1. Such a treatment gives perfect results in a much shorter time.

Finally, the two processes can be combined in an "oscillating anneal", in which the temperatures fluctuate about Ac_1; on heating, partial solution takes place with a trend toward the coalescence of the residual cementite; on cooling, precipitation on the undissolved globules which, on growth, become more difficult to put into solution subsequently. The process can take place either by alternating slow heating and cooling, or by rapid heating into the Ac_1 transformation range followed by a stay at thermal levels below Ac_1. This produces a structure of large globules with low hardness.

ALBERT M. PORTEVIN
Bessemer Medalist

Books for Finland

YELLOW SPRINGS, OHIO

To the Readers of METAL PROGRESS:

Finland has an excellent and keenly scientific minded technical institute known as Teknillinen Korkeakoulu. During the war its library was bombed and totally destroyed.

On my recent trip to Finland for the American Friends Service Committee, I discussed the situation with Dr. Martti Levon, director of the institute. He said he would welcome any gifts of scientific and technical books or periodicals from America to replace those destroyed. In the remarkable efforts for recovery that the Finns are making, the lack of technical library facilities is a very serious handicap. It would be a practical act of friendship to a nation that holds America in high regard if we should contribute good technical books and periodicals to this library.

Any such gifts should be marked for the Institute of Technology, Helsinki, and sent to the Legation of Finland, 2144 Wyoming Ave., N.W., Washington, D. C. Dr. K. T. Jutila, the Finnish Minister, will arrange for their being shipped to Finland.

ARTHUR E. MORGAN
American Friends Service Committee

Width of Crack Discoverable by Deep Etching

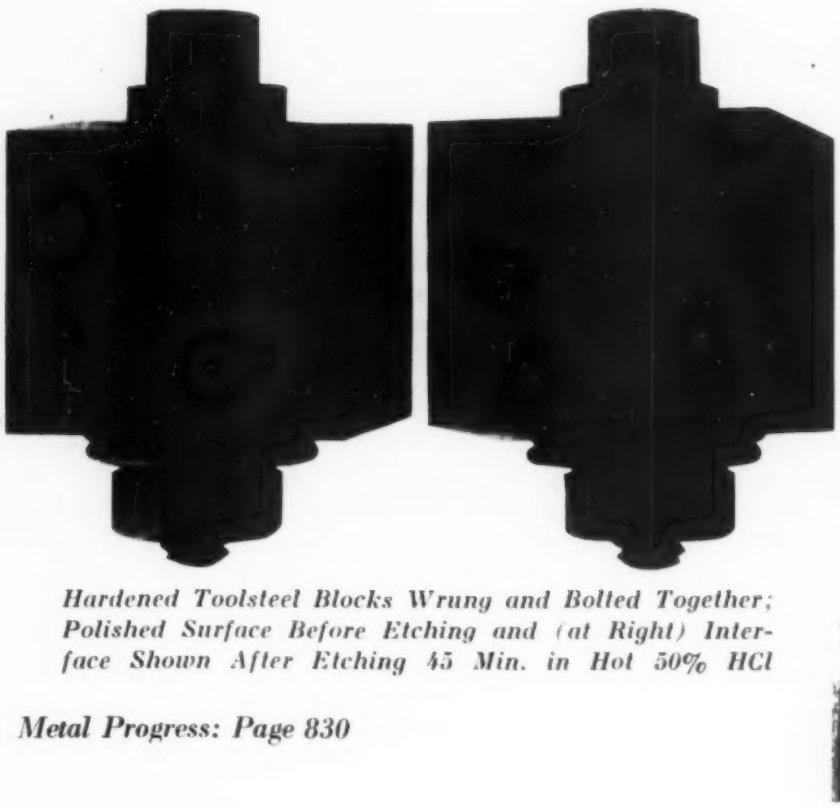
MINNEAPOLIS, MINN.

To the Readers of METAL PROGRESS:

In an effort to learn just how small a crack or break in the metal could be detected by the usual routine metallographic polishing and etching procedure, two small blocks of carbon toolsteel were prepared in such a manner as to allow two flat surfaces to be securely bolted together. The two pieces were hardened and given a subzero stabilizing treatment, followed by grinding and lapping of the two flat faces to be fastened together. The flatness of the surfaces was such that the two pieces adhered to each other in the same manner that gage blocks do when one is slid or wrung over the other. The two were then securely fastened together by a bolt passing through a hole in the center of each block.

Metallographic polishing and etching of an edge face of the joined blocks were carried out in the usual manner. Microscopic examination of this surface was then conducted at both high and low power, and as a last step the joined blocks were macroetched in a 50% solution of hydrochloric acid in water at 170° F. for 45 min.

Microscopic examination of the prepared surface etched in the usual manner (10 sec. in 10% nital) revealed the expected microstructure of a few undissolved carbides in a matrix of fine martensite. It was anticipated that careful examination of the center section of the polished and etched surface



Hardened Toolsteel Blocks Wrung and Bolted Together; Polished Surface Before Etching and (at Right) Interface Shown After Etching 45 Min. in Hot 50% HCl

would reveal the contact line of the two joined blocks, inasmuch as one would at least expect a definite break in the continuity of the metallographic constituents at the interface. However, it was impossible to detect any crack or discontinuity except at the outer edge of the polished face, where it seemed likely that there was not enough pressure from the bolt to hold the two faces together tightly.

Additional time in the nital etching solution had the effect of darkening the appearance of the martensitic microstructure as well as very faintly bringing out the contact line of the two joined blocks. However, the very faint indication of the joint was not continuous across the polished face and it is probable that the break in the surface would not be detected by the usual microscopic examination.

Macroetching in hot hydrochloric acid, however, gave a very pronounced indication of the contact plane of the two blocks and left no doubt as to the location of the joint, as shown in the view at the bottom of the preceding page.

Wet magnafluxing of the joined blocks also gave no indication of the location of the joint. Therefore, it appears that macroetching in a hot hydrochloric acid solution or other suitable etchant is the only reliable inspection method for showing up a discontinuity as small as that which would result from the fastening together of two optically flat hardened and lapped blocks.

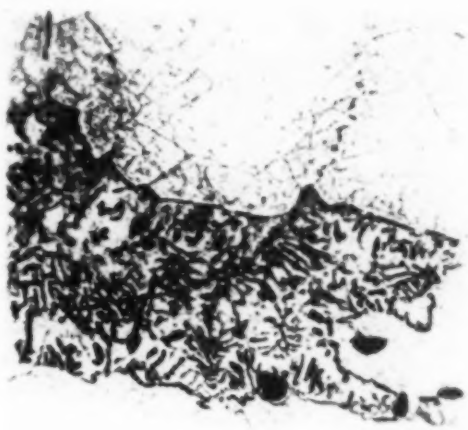
RUSSELL H. LAUDERDALE
Metallurgist
Northern Ordnance, Inc.

Tiger, Tiger, Rah, Rah, Rah!

NICETOWN, PHILADELPHIA

To the Readers of METAL PROGRESS:

While investigating one of the new "superalloys" this skulking tiger crept into the optical field. There may be some big game hunters in the A.S.M. who would propose that we go on *safari*. On the other hand, others who have come under the influence of Cornell, Yale, or other large eastern universities in the Ivy League, may suspect that some Princetonian has merely strayed over into the Penn bailiwick.



MRS. I. M. POPPE
Research Dept.
The Midvale Co.

Sponsored Research in Britain

LONDON, ENGLAND

To the Readers of METAL PROGRESS:

Metallurgical research in Britain falls mainly into four groups: (1) Endowed research work, such as is carried out in our universities; (2) investigations conducted in government establishments, like the National Physical Laboratory, at Teddington, and (3) cooperative research, as typified by the activities of the British Nonferrous Research Assoc. and the British Iron and Steel Research Assoc. in conjunction with industry. Consequently, few of these investigations are competitive. Most metallurgical works have, of course, their own laboratories (4), but hitherto there has been no separate institution for sponsored research. It was of interest, therefore, to witness the recent establishment of the Fulmer Research Institute at Stoke Poges, Bucks., because it emulates the system so long and successfully operated in America by the Battelle, Mellon and Illinois Institutes.

Sir Stafford Cripps, President of the Board of Trade, officially opened the premises (which are situated in a converted country manor), since the present government is doing its utmost to encourage research institutions in particular industries. Under the new industrial development and organization act, it will be one of the functions of development councils to support joint research organizations, but these will not cover the whole ground, and the initiative of the starting of this institute was heartily welcomed. The Chairman is a well-known industrialist, Col. W. C. Devereux, who, when he controlled High Duty Alloys, Ltd., established one of the best equipped of our research laboratories. He discovered that one of the greatest problems was to find a means of setting up laboratories on an adequate scale for the small or medium size business. He realized that an increased number of manufacturers would be able to benefit from the application of research work if it were possible to hire the services of a fully established research team. The opportunity arose two years ago for him to try such a scheme in connection with a group of companies which he was founding.

The laboratory is of moderate dimensions, but there is adequate apparatus to provide a basis for most forms of metallurgical research. Its future will

depend on the ability of its staff to provide worthwhile results for those utilizing its services. The most important investigations now in progress are in the development of new alloys for service at high temperatures; researches on aluminum base alloys; and on a process for refining impure aluminum. The last is a new method of catalytic distillation based on the existence of monohalides of aluminum, stable at low pressures and high temperature, which can be formed by passing the normal trivalent halides over aluminum at high temperatures and low pressures, and which decompose to the metal and the trivalent halide at lower temperatures. The principle is likely to be applicable to other metals, and sponsorship for researches on the refining of other metals on this principle is sought.

As the director of research, E. A. G. Liddiard, stated at the opening ceremony, the idea is as yet bigger than the institute, and although it is starting with metallurgical research mainly in the nonferrous field, ultimately it is hoped to provide an establishment so equipped and staffed that most types of industrial research may be undertaken. When a problem is submitted, the management will first decide whether the institute can tackle it, and whether it is likely to cut across any existing research contract. (Investigations on similar projects are not carried out simultaneously for more than one sponsor, unless the sponsors agree to share the work.) Having decided that a given problem can be taken on, the prospective sponsor is asked to pay a retaining fee to cover the cost of a preliminary survey to define the problem, to find out what is exactly involved, the staff and equipment likely to be needed, the probable time required, and the cost. The cost may appear high in relation to that of maintaining investigators elsewhere — in universities, for example — but it represents the real expense of research. University research is cheaper due to endowments, and to the fact that academic workers accept lower salaries in order to work for higher degrees, while supplementing their income by teaching.

The Fulmer Institute is to operate with no public assistance, such as grants or relief from rates and taxes; there are, however, compensating advantages in the ability of the staff members to devote all their time and energies to tackling research problems and in the more vital and competitive projects that will be submitted by free and individual industrial enterprises. The research work done by the cooperative and state-aided research organizations is rarely of this type and is more often on well-known and general problems common to sections of industry.

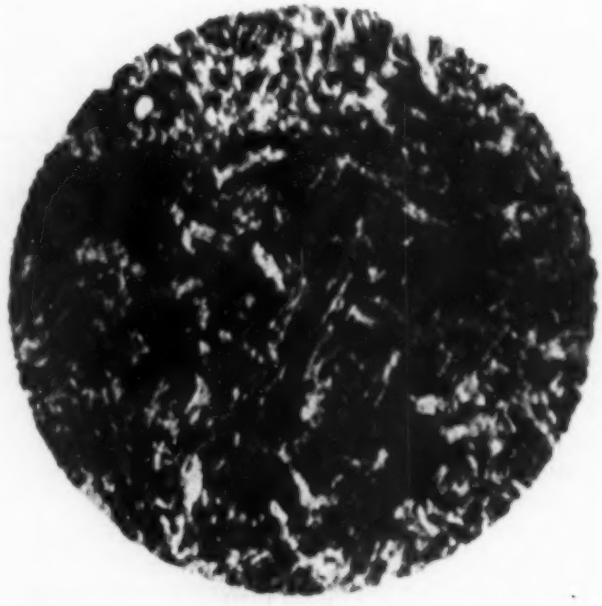
TOM BISHOP

Creep in Hot Valve Springs

TURIN, ITALY

To the Readers of METAL PROGRESS:

In my letter published in the February issue I described some of our investigations on the creep of small valve springs at relatively moderate temperatures (175° F.). These studies are continuing, and we were interested to observe the good behavior of austempered chromium-vanadium



Cr-V Spring, Austempered at 595° F. 2500 ×

steel whose analysis is 0.48% carbon, 1.20% chromium and 0.15% vanadium. As in the tests described in the earlier communication, the torsional stress is 55,325 psi. as calculated by Wahl's formula. The results are summarized thus:

	Loss in Height, %		
Spring History	After 1 Hr.	After 100 Hr.	After 200 Hr.
1	0.80	2.93	3.00
2	0.78	2.07	2.42

Spring No. 1 was quenched from 1520° F. and tempered at 850.

Spring No. 2 was austenitized at 1550° F., transformed at 595° F. in a molten salt bath. Its microstructure is as shown above.

We believe this gives quantitative evidence of the value of austempering this alloy spring wire for diesel engine work.

ALBERTO OREFFICE
Chief Engineer, Steel Dept.
The Fiat Co.

Maintenance of Metallic Trim at Rockefeller Center

By Myron Weiss
New York City

Metallurgists, corrosion specialists, testing engineers, as well as architects and building managers, are interested in the long-time resistance of exposed metal to atmospheric influences. Atmospheres vary greatly, however, in their destructive capabilities, ranging from sea shore and heavy industrial to benign rural. New York City has one of the worst. This report of 10-year experiences at one of the best maintained building groups should therefore reveal the capabilities of modern metals.

FOR THE VERTICAL ACREAGE of Rockefeller Center's 14 buildings in New York, John D. Rockefeller, Jr., wanted external metal trim that would harmonize with the gray-stone curtain walls reaching in one building 850 ft. up, that would remain looking like metal, and that would require the least attention for maintenance. This posed quite a problem to architects and metallurgists, for in the turbid atmosphere of New York metals foul quickly and annoyingly.

Therefore, the way in which Rockefeller Center metals have resisted years of atmospheric corrosion is a measure of their general usefulness in architecture. The air of New York City is smutty with soot from soft-coal burning factories, apartment houses, two-family homes, tugs and ships; from furnace ashes, incinerator gases, vehicle exhausts; from sea-salty droplets; from street debris dropped by human and domestic animals. Temperature changes also accentuate the action — both diurnal change from sun-baked summer noon to quenching rain at midnight, and seasonal change from summer's heat to penetrating frost at winter. Any imperfection in the surface — either of the metal itself or of a protective layer — or any hidden joint will open in the cooler hours or days, drawing in and trapping the day's debris or moisture, slightly acid with sulphurous smoke or chloride sea salt.

In sum, air-borne gums and gases cause great damage and eyesore to metals used out of doors in New York. Conditions are so intensified here that their record of resistance should indicate what they might do in other communities.

Rockefeller Center architects* had a dominating ideal to obey. This was "the bringing of new beauty to commercial construction". This meant that they must avoid any apology for unavoidable corrosion — always called "patina", as though an Italian word would make a discolored surface look any better. This also forbade the use of naked copper which was bound to discolor the surrounding stone. (Copper sheeting is used in a few places on Rockefeller Center roofs, but it is everywhere coated with lead — a not too satisfactory protection, as experience elsewhere proves.)

Early plans for the buildings called for metal spandrels to fill and ornament the spaces between the tops of window frames and the bottoms of frames next above. The late architect Raymond Hood recommended stainless steel for its permanent silvery color which would be close in tone to the stone walls, for its light reflecting qualities, and for its durability. Proposals were made to

*One of whom, Wallace K. Harrison, is now director of planning and head of the board of design consultants of the 17-acre United Nations center about to be built six avenues to the east.

cast such stainless spandrels, but the surface of the metal as it came from the sand molds was not smooth enough and all the polishing facilities available in the early 1930's in all the mills of this country would not have been able to polish the vast quantity fast enough to keep up with the rising courses of masonry. So cast aluminum spandrels were used on most buildings, and stone elsewhere.

Stainless steel, nonetheless, did get a significant place in decorating the buildings. Notably, just above the Rockefeller plaza entrance to the Associated Press Building hangs a 10-ton bas-relief. Symbolizing the activities of the press, it is the first heroic sculpture ever cast in stainless. The alloy is 24% chromium, 12% nickel — thus avoiding the more tractable 18-8 which has not always resisted the pitting type of corrosion in sea shore exposures. Its entire surface was ground by the Nisei artist Isamu Noguchi after erection, the abrasive wheels traveling in carefully studied angles so as to disperse the reflections from objects far and near.*

For all exterior windows, except at ground level and at mezzanine locations, painted steel sash and frames are used at Rockefeller Center.

Bronze makes up all trim for store fronts and doors. An exception is one big wooden window frame in the Time & Life Building which is painted to look like bronze.

For ornament, 60 ft. above the sidewalk, the Center Theater carries on its north wall a rectangular 18x35-ft. plaque of cast aluminum enameled in colors. Radio City Music Hall also has on its south wall at the same height three enameled cast disks 18 ft. in diameter.

Of all the metals used as exterior trim on these buildings the finish-ground stainless plaque above the Associated Press doorway has required but little maintenance and has held up with no deterioration, according to the Rockefeller Center maintenance staff. All that has been necessary to restore it to its original brightness has been a semiannual scrubbing with water and detergent to remove the dirt which settles on it. After eight years no corrosion has appeared.

The steel window frames must be repainted every three to five years.

Two of the painted outside doors at sidewalk level have corroded along their bottom edges where rain, dogs and passersby have spattered them. The rusted bottoms look to be of steel.

The thousands of cast aluminum spandrels have never been touched. They remain covered with oxide and grime. To the eye, from the sidewalk, those metal spandrels are indistinguishable from the stone of the walls.

Nor have the four great enameled cast aluminum plaques on Theater and Music Hall ever been cleaned. Rain washes enough smut off the enamel to let the colors show.

Bronze frames of ground and mezzanine windows and the bronze doors have stood up excellently. A staff of four bronze finishers working by day and two more working by night are on the job continuously. All of that bronze is lacquered. The men strip and replace the lacquer and wipe down the protected surfaces. They do no polishing — that would require an enormous staff. On one building, the Center Theater, bronze window frames were polished for a while, but the surfaces oxidized and, after polishing, showed irregular streaks. Eventually they were thoroughly cleaned and polished, and then were allowed to oxidize naturally, as similar bronzes on other buildings have since time immemorial. Maintenance men simply wipe and oil those oxidized bronze surfaces about once each month.

Store doors are kept bright by a thorough cleaning in the first place, followed by a coat of lacquer. Men strip that lacquer periodically and recoat. Much of the bronze trim is of bright color. This also is lacquered after a first thorough cleaning. Then it is oiled and wiped once each week. Once each year the lacquer is replaced.

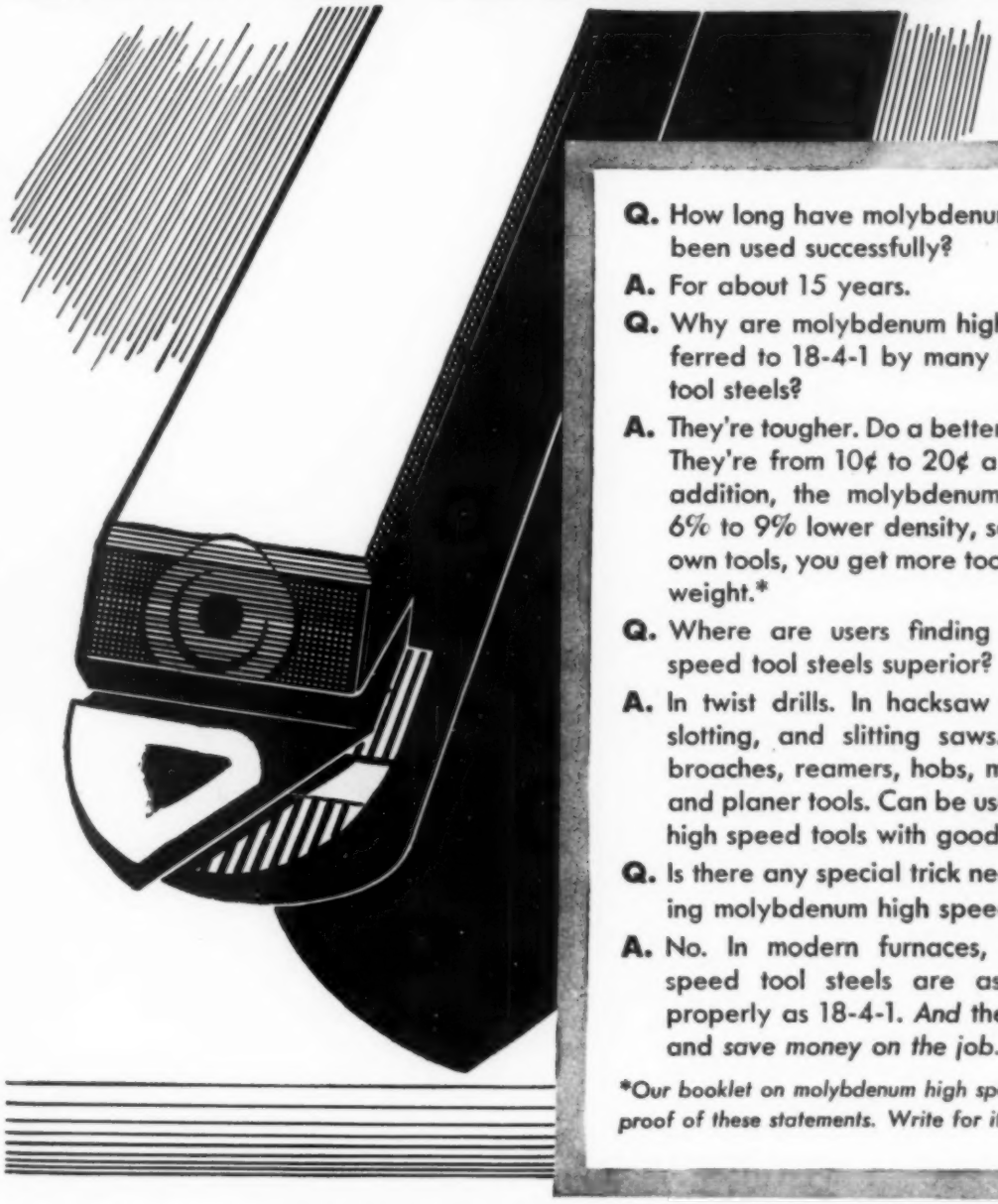
Interior bronzes used for handrails, moldings, inside window jambs, and so on, are lacquered, stripped and relacquered periodically. Other interior bronzes are merely wiped down as long as they show no tarnish, but when they start to discolor they have their worn lacquer replaced.

Rockefeller Center's maintenance staff does not use polishing abrasives or liquids on any of the finished bronze surfaces.

Possibly the above factual account of experience with exposed metal in the world's most important architectural mass erected in the 20th century may be concluded with a few generalizations, and one speculation: Of all the metals, enameled aluminum and cast 24-12 stainless show highest repellance to atmospheric deposits and corrosion effects. Cast aluminum accumulates adherent soot almost as fast as bare stone and as rapidly loses its luster. The beauty of bronze is fleeting unless a protective lacquer is constantly maintained. Metal window frames are mandatory for fire protection; the high and increasing expense of painting steel at 4-yr. intervals doubtless causes the owners to regret that aluminum was not installed at the outset.

*A complete story about the manufacture of this nine-section bas-relief was given by H. H. Harris in *Metal Progress* for May 1940, p. 537.

QUIZ ON HIGH SPEED STEELS



Q. How long have molybdenum high speed steels been used successfully?

A. For about 15 years.

Q. Why are molybdenum high speed steels preferred to 18-4-1 by many large consumers of tool steels?

A. They're tougher. Do a better job for less money. They're from 10¢ to 20¢ a pound cheaper. In addition, the molybdenum steels have from 6% to 9% lower density, so if you make your own tools, you get more tools for a given gross weight.*

Q. Where are users finding molybdenum high speed tool steels superior?

A. In twist drills. In hacksaw blades. In milling, slotting, and slitting saws. In taps, chasers, broaches, reamers, hobs, milling cutters, lathe and planer tools. Can be used for all classes of high speed tools with good results.

Q. Is there any special trick needed in heat treating molybdenum high speed tool steels?

A. No. In modern furnaces, molybdenum high speed tool steels are as easy to harden properly as 18-4-1. *And* they cost much less—and *save money on the job.*

**Our booklet on molybdenum high speed steels will give you proof of these statements. Write for it.*

MOLYBDIC OXIDE—BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"
CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

Climax Molybdenum Company
500 Fifth Avenue · New York City

MOLY

Personals

ROBERT J. DUNCAN has joined the Bethlehem, Pa., plant of the Bethlehem Steel Co.

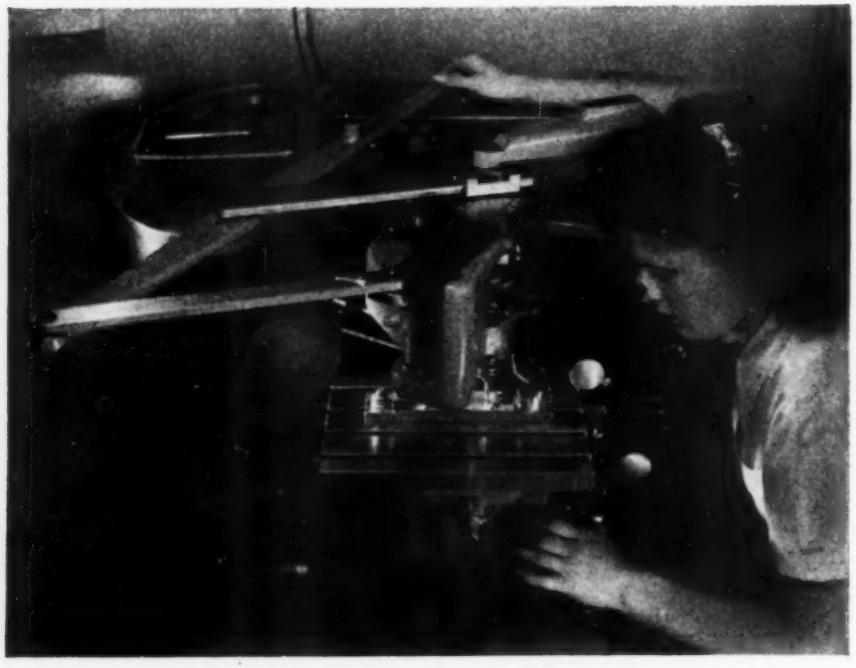
HENRY MUSCH, 3RD, is now production engineer at Marlin Firearms Co., New Haven, Conn.

Leaving Textron, Inc., C. G. ASCHMANN, JR., has accepted a position as production engineer at Watson Flagg Machine Co., Paterson, N. J.

Resigning his position at Lincoln Electric Co., DONALD E. NULK has accepted a research assistantship at Pennsylvania State College where he plans to work for an advanced degree in metallurgy.

Banner Iron Works, St. Louis, Mo., announces that MAX R. WISE of Tulsa, Okla., will serve as their sales agent.

R. W. DOUGHERTY, formerly in charge of the Kalamazoo office of the Lindberg Engineering Co., is now in charge of the new office in Philadelphia.



She SEES it better
she MAKES it better

This operator *knows* that her work will pass inspection. With the aid of a Spencer *Stereoscopic* Shop Microscope she sees smaller details and controls her operation more accurately. The result is less scrap; lowered costs; increased profits.

Designed to meet critical wartime requirements, the Spencer Shop Microscope offers manufacturers new possibilities for quality control at every point—inspection of raw materials, toolmaking, tool inspection during operation, fine machining, and final inspection. Equipped with or without standard base, it is adaptable and can be permanently mounted to your equipment. Choice of optics offers magnifications from 9X to 54X.

For further information write Dept. Y119.

- ★ INJECTION JET DRILLING
- ★ WATCH ESCAPEMENTS
- ★ FINE ENGRAVING
- ★ PRECISION GRINDING
- ★ HAND BROACHING
- ★ SMALL PARTS INSPECTION
- ★ LENS MOUNTING
- ★ DIE SINKING
- ★ MANY OTHER TOOL-MAKING, FABRICATING, AND INSPECTION PROBLEMS

American Optical
COMPANY
Scientific Instrument Division
Buffalo 15, New York

Manufacturers of the **SPENCER** *Scientific Instruments*

DAVID F. SKLAR, formerly with Wilson Mechanical Instrument Co., Inc., has formed the Kent Cliff Laboratories, Peekskill, N. Y., for consultation, development and manufacture of hardness testing equipment and similar apparatus.

In addition to being vice-president of General Metals Corp. and in charge of the Oakland Iron, Steel and Malleable Div., WILLIAM E. BUTTS has been recently elected president of Enterprise Engine and Foundry Co., San Francisco.

J. G. MAGRATH has been selected as executive secretary of the American Welding Society. He has most recently been sales manager of the McAlear manufacturing division of Climax Industries, Inc.

After four years in research and development work for the Engineering Board, HERBERT F. KROHN returned to Bethlehem Steel Co. and now holds the position of contact metallurgist.

LAWRENCE F. TRAIN, formerly metallurgist, The John Bertram & Sons Co., Ltd., is now metallurgical engineer in charge of the development and research department, Craig Bit Co., Ltd., North Bay, Ont., where he will specialize in problems connected with the use of detachable rock bits in the mining and constructional fields.

WAYNE E. MARTIN, formerly sales manager of the Beryllium Corp. of America, is now associated with William F. Jobbins, Inc., in charge of sales in the Cleveland district.

HENRY J. KOZLOWSKI is on leave of absence for one year from the physical metallurgy research laboratories, Bureau of Mines, Ottawa, Canada, to undertake postgraduate studies in the school of industrial metallurgy, University of Birmingham, England.

Atlantic Steel Co., Atlanta, Ga., announces that H. A. GROVE has joined the organization as metallurgical engineer, coming from Republic Steel Corp. which he joined in 1933 and where he has been mill metallurgist on alloy flat products since 1936.

J. N. MRGUDICH has transferred from chief, photographic branch, U. S. Army Signal Corps, to research director, electrical division, Winchester Repeating Arms and Bond Electric Corp., Olin Industries, New Haven, Conn.

for HIGH STRENGTH

at low temperatures

REVERE COPPER and COPPER ALLOYS

● Revere Copper and copper-base alloys are a "natural" when dealing with applications involving subnormal temperatures all the way down to liquid oxygen (-306°F.) and below.

Copper and its alloys possess the valuable characteristics of becoming increasingly stronger, the lower the temperature, *with no attendant loss of ductility*, and *with no tendency toward brittleness or "notch-impact" sensitivity*.

For example, note the rise in strength, ductility *and* resistance to impact for two copper and brass alloys:

Alloy	Temp. °F.	Tensile Strength, p.s.i.	Elongation % in 2 in.	Impact Resistance, Kg-m per sq. cm.
Electrolytic				
Tough Pitch	68	58,700	8.4	6.6
Copper (Cold Rolled Strip)	-295	64,800	11.2	7.4
Yellow Brass	73	85,400	6.3	8.1
(Cold Rolled Strip)	-295	102,900	10.1	9.4

Other Revere Alloys, such as Herculoy (High-Silicon Bronze, A), show similar improvement in these important mechanical properties.

If you make or are contemplating the manufacture of liquid oxygen equipment, you will be playing safe to specify copper-base alloys. Get in touch with Revere for full information on the low-temperature physical characteristics of Revere metals.

. . .

REVERE

COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

230 Park Avenue, New York 17, New York

Mills: Baltimore, Md.; Chicago, Ill.; Detroit, Mich.; New Bedford, Mass.; Rome, N. Y.

Sales Offices in Principal Cities. Distributors Everywhere.

Personals

Titanium Alloy Mfg. Co. announces the appointment of N. R. ARANT to its metallurgical field staff. Mr. Arant was formerly with Republic Steel Corp. and Universal-Cyclops Steel Co.

R. G. MCELWEE, foundry alloy division manager for Vanadium Corp. of America, Detroit, has been elected chairman of the gray iron division of American Foundrymen's Association.

B. L. AVERBACH was awarded the degree of Sc.D. in metallurgy at the Massachusetts Institute of Technology in 1947 and has accepted an appointment as an assistant professor of metallurgy there.

JOHN P. NIELSEN has been appointed associate professor of metal science at New York University.

ARTHUR S. COFFINBERRY has joined the Los Alamos Scientific Lab. as a group leader of the physical metallurgy group, chemistry-metallurgy division.

ROBERT R. GREGG, foundry manager of Reliance Regulator Co., Alhambra, Calif., was elected an international director of American Foundrymen's Association.

Welland Electric Steel Foundry, Ltd., Welland, Ont., announces the appointment of H. BARNETT as vice-president and general manager. Mr. Barnett has been works manager for the past three years and had previously been director of research of Electric Steels, Ltd.

ROBERT TALMAGE has organized Applied Powder Metallurgy of Norwalk, Conn., a consulting service in the application, design, installation and operation of equipment to produce parts from metal powders as well as development work on new materials.

Resigning his position as director of tests and inspection for Electro-Motive Div. of General Motors Corp., JOHN H. HRUSKA now serves several industries as consulting engineer, specializing in metallurgical and welding problems, at Hinsdale, Ill.

American Chain & Cable Co., Bridgeport, Conn., has announced that V. E. LYSAGHT has assumed direction of sales of Andrew C. Campbell division. Mr. Lysaght will continue his duties with Wilson Mechanical Instrument Co.

JOHN W. LOHNES, district sales manager of the Vanadium Corp. of America in its New York and Chicago offices for the past few years, has been appointed general sales manager of the International Graphite and Electrode Corp., St. Marys, Pa.

Sylvania Electric Products, Inc., announces that BERNARD KOPELMAN has rejoined their organization as section head of the metallurgical research group. Mr. Kopelman has recently been associated with U. S. Finishing Co.

After five years as teaching specialist in forging, welding and heat treating in the mechanical engineering department at Stanford University, ASA A. ROBLEY has returned to Oregon State College, Corvallis, Ore., as assistant professor in the department of industrial engineering in charge of the forging and welding laboratory.

NEWTON C. PRITCHARD has recently left the Bureau of Reclamation, Denver offices, to accept a position with the C. F. Braun Co. at Alhambra, Calif.

BUT . . .

The motor-wise public of this generation demands the best in automotive engineering. Where aluminum — and its alloys — are being processed

Alodizing* With Alodine*

is as drastic an improvement over methods of the past — as today's automobiles are over the horseless carriage. "ALODINE"-coated and sealed aluminum — either painted or unpainted — is effectively protected. "ALODINE" requires no electricity or special skill — no high temperatures. In two minutes, or less, the job is finished. ALODIZED* aluminum is highly corrosion resistant — provides a tenacious bond for paint — saves time and labor — and reduces production costs.

CHEMICALS ACP PROCESSES

RUST PROOFING AND PAINT BONDING
Granodine *
Duridine *
Alodine *
Lithoform *
Thermoil-Granodine *

RUST REMOVING AND PREVENTING
Deoxidine *
Peraline *

PICKLING ACID INHIBITORS
Rodine *

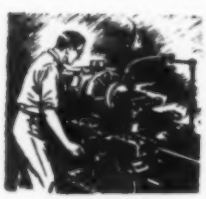
* "ALODINE" ® for Metal Coating Chemicals

AMERICAN CHEMICAL PAINT CO.
AMBLER ACP PENNA.

Professional Worriers!

Every business, time and again, runs into production snags. When the problem is *lubrication*, we're often called in to do the worrying. And eight times out of ten we come up with the right answer—*fast*. Because that's our job day in, day out, year after year—putting petroleum to work *efficiently*. This backlog of experience, coupled with the world's finest lubricants and fuels, is your best reason for calling Cities Service next time trouble calls on you.

CITIES SERVICE STOPPED TROUBLE HERE!



A screw products company in Cuyahoga Falls, Ohio, called on Cities Service for advice on machining a part of an intricate mechanism made of aluminum that required extreme accuracy and finish. Chillo Oil No. 22 was recommended. Thereafter, the manufacturer reported the machined work was not only well within the required tolerances, but the work had a mirror-like finish. Tool life was also phenomenally good.

A brick and tile company in Iowa suffered numerous failures of the main drive-shaft bearings in their Hammer Mill Crushers. Cities Service engineers recommended Pacemaker Oil No. 2. The last report from the company said that since they standardized on this lubricant, no bearing failures have occurred.

"We use Solvent No. 26 for cleaning surplus oil and grease out of electric clock movements and we find it unexcelled for this purpose" ...so writes the president of an Illinois watch repairing and rebuilding concern after continued use of this remarkable new Cities Service metal cleaning fluid.

A bus company executive in Cleveland, Ohio, recently said, "During the past four years, we used Cities Service Heavy Duty type oil with outstanding results—minimum wear, freedom from sludge and no engine failures—which has enabled us to give uninterrupted service to our customers."

CITIES SERVICE OIL CO.
New York—Chicago

CITIES SERVICE

ARKANSAS FUEL OIL CO.
Shreveport, La.

Cities Service Oil Company
Room 258, Sixty Wall Tower
New York 5, N. Y.

Gentlemen: I have a production problem that involves lubrication. I would like to discuss it with one of your lubrication engineers, without obligation, of course.

NAME_____

COMPANY_____

ADDRESS_____

CITY_____ STATE_____

Personals

Previously associated with the Arthur Tickle Engineering Works, Brooklyn, N. Y., A. M. WATT has recently joined the New York office of the H. K. Ferguson Co., in the specification department.

Having received his degree in mechanical engineering from Cornell University, STEPHEN MATOVICH, JR., is now mechanical engineer for the Solvay Process Co., Hopewell, Va.

ROBERT T. HOWARD, formerly of Massachusetts Institute of Technology, has joined the staff of the chemistry and metallurgy division of Los Alamos Scientific Laboratory as a metallurgist.

Resigning his position as secretary and works manager of Whipple & Choate Co., FRANK B. DIANA is now associated with Z. Wagman and Sons, Ltd., Toronto, Ont.

JACK CHELIUS, formerly at south works, Carnegie-Illinois Steel Corp., has joined the Fansteel Metallurgical Corp., North Chicago, Ill.

DAVID N. CRUMP has been transferred by National Malleable & Steel Castings Co. from metallurgist at the Melrose Park, Ill., plant to field engineer in the field engineering section in Cleveland.

HAROLD H. DAUGHTERS is now employed in the metallurgical department of Kaiser Steel Co., Fontana, Calif.

EARL L. CASEY has been promoted to general superintendent of production and maintenance at Geophysical Service, Inc., located in Dallas, Tex.

RAY TREON, JR., graduated from the Missouri School of Mines in August and is now attending the Chrysler Institute of Engineering at Highland Park, Mich.

DONALD FEATHER, who received his B.S. in metallurgy from the University of Wisconsin this year, has received an appointment as instructor in the department of metallurgy.

BRALY S. MYERS has been appointed research chemist for International Harvester's manufacturing and research division in Chicago.

WILLIAM J. CRAIG, formerly with Cornell Aeronautical Lab., Buffalo, is now at the University of Illinois, working on fatigue of metals, while on the staff of theoretical and applied mechanics department.

J. E. BOYLE has been appointed general manager of Back River Power Co., Montreal, Canada.

CARL F. BURLING has been transferred by Lindberg Engineering Co. from the Boston office to the Buffalo, N. Y., office.

Formerly with Weber Engine Co., EARL BEYERLEIN is now metallurgist at the Bettendorf works, J. I. Case Co., Bettendorf, Iowa.

H. V. MENKING is now in charge of the industrial machinery division of Reynolds Metals Co.

RICHARD P. FROHMBERG has left Wellman Bronze & Aluminum Co. to attend Case Institute of Technology as a graduate student in the department of metallurgical engineering.

J. HOWARD KITTEL, metallurgical engineer at the National Advisory Committee for Aeronautics, flight propulsion laboratory, Cleveland, is now on leave for research work at the Atomic Energy Commission's Argonne National Laboratory, Chicago.

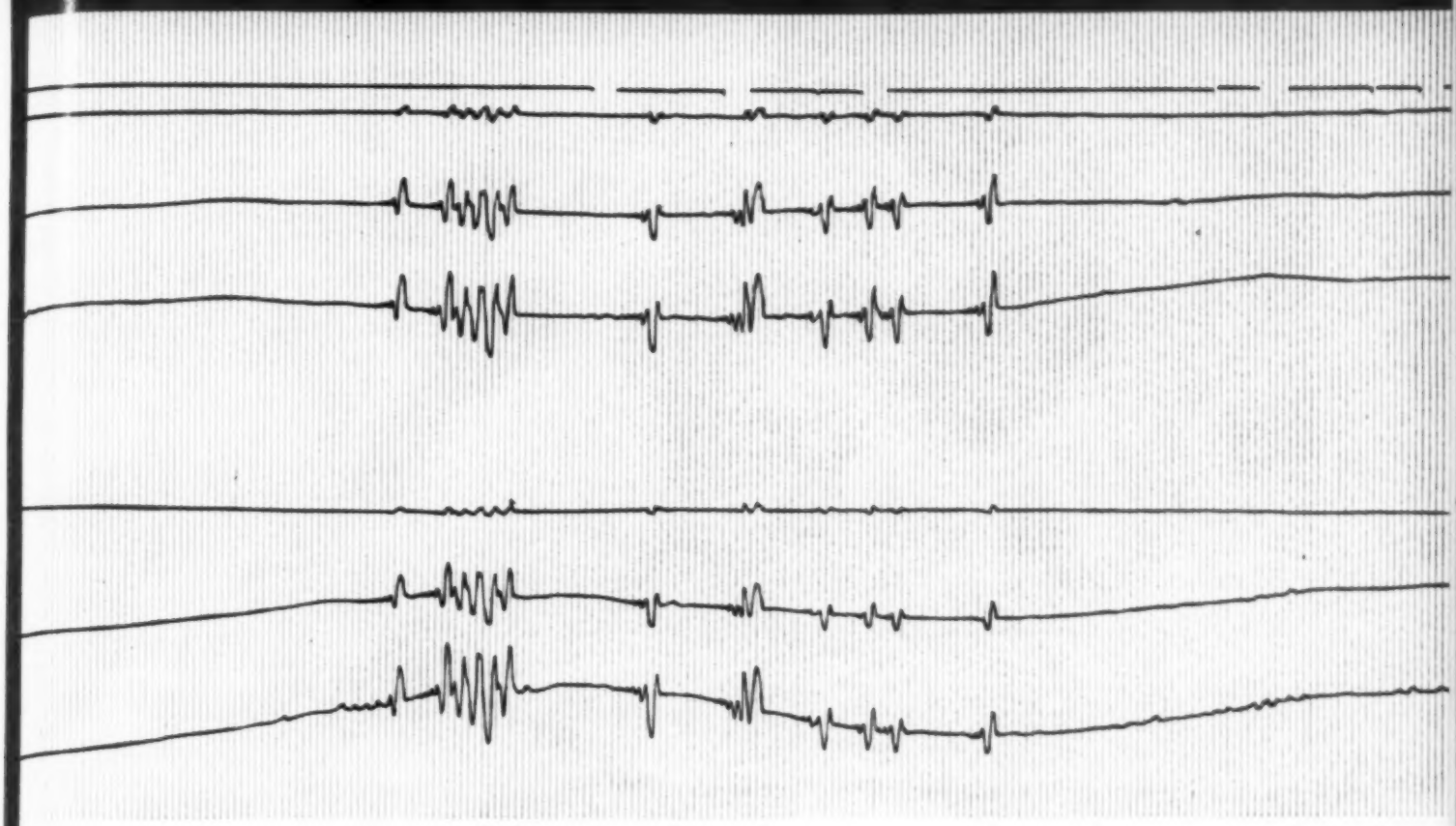
CUT HIGH-SPEED STEEL TOOL COSTS

High-Speed Steel Tools, Cutters, Broaches, etc., of molybdenum, tungsten and cobalt are given longer useful life when hardened the Sentry Way with the Sentry Diamond Block Method of controlled atmosphere. Advantages are maximum hardness, uniform quality, no scale, no decarburization, bright finish, dimensions and shape maintained and finishing operations eliminated. One unskilled operator can tend several furnaces.

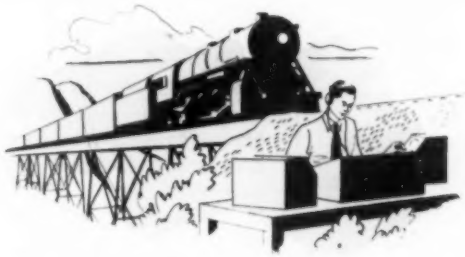
Sentry Electric Furnaces are quick to heat, economical to operate, flexible, clean. There are horizontal and vertical models in sizes to meet your needs.

Write for new 12-page descriptive catalog. Ask for bulletin 1054-A5.

The Sentry Company
FOXBORO, MASS., U. S. A.
Sentry DIAMOND Block



Picture of a bridge groaning under load...



. . . photographic stress analysis is one of many industrial uses for light-sensitive Kodak recording materials.

By cementing strain gauges smaller than postage stamps to external surfaces, test engineers can find out about structural behavior deep inside the material under stress . . . so sensitive is the response of these little devices to vibration and strain.

An important contribution to such sensitivity in instruments of this type is the wide latitude of Kodak photographic recording materials that are available. These may be had in all sizes and speeds for nearly every type of instrument.

Instrument Recording

. . . another important function of photography

Kodak is continually developing new recording products, and is glad to discuss them with you—so your new instruments may take full advantage of the finest in photographic recording.

Why not utilize the greater sensitivity and speed of photographic recording for your instruments? Why not find out how well the new Kodak high speed recording papers will work in your equipment? Just write to

EASTMAN KODAK COMPANY
Industrial Photographic Division
Rochester 4, N. Y.

Eastman Kodak Company
Industrial Photographic Division
Rochester 4, N. Y.

☐ Please send me your book "Recording Materials."

☐ Please send information on your new high speed recording papers.

Name_____

Company_____

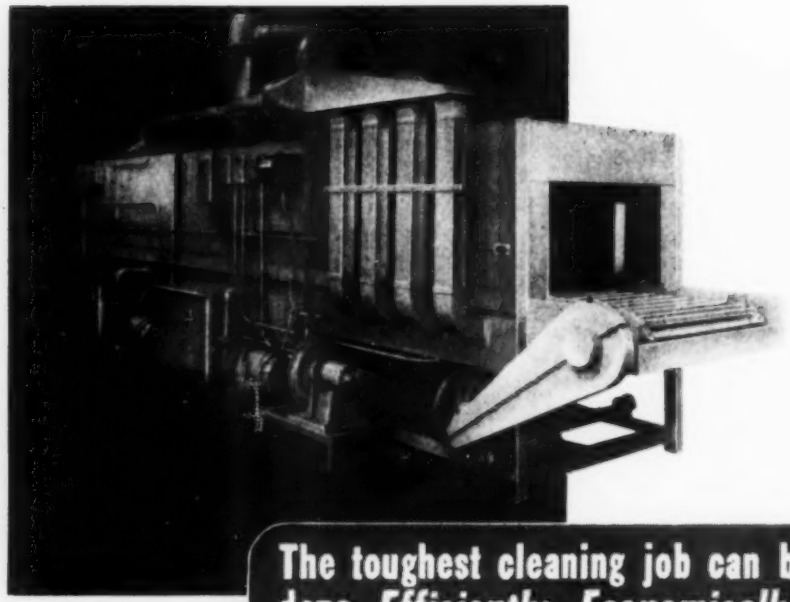
Department_____

Address_____

City_____

State_____

Kodak



The toughest cleaning job can be done *Efficiently, Economically!*

WHY BE SATISFIED WITH LESS?

NO metal parts or products cleaning problem is too tough for A-F Engineers! . . . Custom-designed, engineered and built especially to clean electric motor housings, parts and assemblies, this A-F Cleaning Machine does its job quickly, efficiently, economically. It washes and rinses and dries by means of high-pressure air blow-off. Gas heaters are automatically controlled. Movement of parts through machine can be regulated by variable speed drive on A-F Conveyor inside.

YOUR PROBLEM IS DIFFERENT?

IF one of our "standard" metal products cleaning machines will not solve your problems, remember that ALVEY-FERGUSON *specializes* in custom-built equipment. Write for literature or a discussion — today.

THE ALVEY-FERGUSON COMPANY

165 Disney Street Established 1901 Cincinnati 9, Ohio

Offices in Principal Cities Coast-to-Coast

CONVEYING EQUIPMENT

Alvey-Ferguson

METAL PRODUCTS CLEANING EQUIPMENT

Personals

WALDEMAR NAUJOKS is now manager of the new forged valve division of the Ohio Injector Co., Wadsworth, Ohio.

WENDELL F. HESS has been appointed head of the department of metallurgical engineering at Rensselaer Polytechnic Institute, Troy, N. Y., to succeed MATTHEW A. HUNTER, who will continue as dean of the faculty.

Carborundum Co., Niagara Falls, N. Y., announces the appointment of GURDON M. BUTLER, JR., as a senior engineer of the research division. Mr. Butler had previously been with the Allegheny Ludlum Steel Corp.

The Johnson Temperature Regulating Co. of Canada, Ltd., announces the appointment of SYDNEY NARVEY as assistant sales engineer and serviceman.

BRUCE S. OLD, of Arthur D. Little, Inc., Cambridge, Mass., industrial research laboratory, has been appointed consultant to the Atomic Energy Commission, division of research, in the capacity of chief metallurgist. He will continue his work for Arthur D. Little, Inc.

After five years at Battelle Memorial Institute as research engineer, ANTON BRASUNAS is now at Massachusetts Institute of Technology studying for his Sc.D. degree and working in the corrosion laboratory as research assistant on high temperature corrosion.

EDWARD P. GRUCO is now assistant chief welding engineer for the Pullman-Standard Car Mfg. Co., Chicago.

F. E. SLATER, formerly with U. S. Steel Corp., National Tube Works, is now with the Aluminum Co. of America, Pittsburgh, as metallurgical engineer in the mechanical engineering department.

HARRIS P. MOYER, formerly with Aviation Corp. and Process Development Corp., is now associated with the A. O. Smith Corp., of Milwaukee.

ROBERT F. REMMIE, with Basic Industries section of the Bipartite Economic Control Group for Germany, is at present stationed at Minden, Westphalia, but will soon be transferred to Frankfurt.

ONE OF A SERIES OF STORIES ABOUT ALLOYING METALS...WHERE THEY COME FROM AND HOW THEY ARE USED

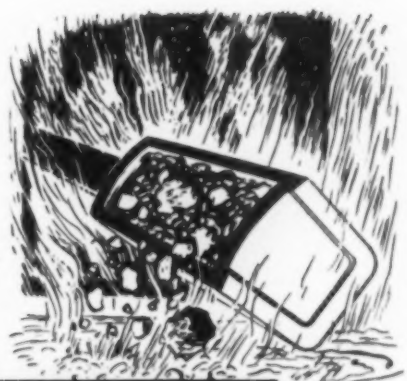
THE STORY OF MANGANESE

12th CENTURY BEAUTY

1 Manganese minerals were known in ancient times and were used to produce the rich colors of medieval stained glass windows. However, it was not until 1774 that the metal manganese was isolated. It became important to steelmakers in 1856 when Sir Robert Mushet used it to perfect the bessemer process.

MOVING MOUNTAINS

2 Mountains of manganese ore from various places throughout the world are shipped each year to the United States to help meet our nation's requirements. In Electromet's furnaces, these ores are reduced to ferromanganese, silicomanganese, and other alloys of high purity.



TAMING THE BREW

3 Manganese is the most important alloy used in steelmaking. It has a powerful attraction for oxygen and sulphur — gathering and removing these impurities as a slag during the deoxidizing process. One of the best of all deoxidizers is silicomanganese — a combination alloy of silicon and manganese.

SQUEEZE PLAY

4 By combining with sulphur, manganese removes the principal cause of hot-shortness — thereby giving steel better rolling and forging properties. It imparts great strength and toughness, and that's why all steels—castings, forgings, and rolled products—contain at least small amounts of this metal.

PUTTING MUSCLE IN STEEL

5 Manganese makes steel tough. Steel containing about 13 per cent manganese is "work-hardening," that is, it possesses the property of increasing in hardness as the metal is worked. Steam shovel teeth, crushing machinery, and railroad switch frogs would quickly wear out, were it not for this property.

Aid To Steelmakers

Electromet's staff of experienced and well trained metallurgical engineers are always ready to assist you with the proper use of ferro-alloys, and help you solve other metallurgical problems relating to melting procedures. These men are familiar with the most efficient and up-to-date shop practices. Their specialized knowledge has assisted customers in solving many metallurgical problems. For further information write for our booklet "Electromet Products and Service."

ELECTRO METALLURGICAL COMPANY
Unit of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.

ELECTROMET Ferro-Alloys and Metals are sold by Electro Metallurgical Sales Corporation, and Electro Metallurgical Company of Canada, Limited, Welland, Ontario.

Electromet
TRADE-MARK
Ferro-Alloys & Metals

If you use
STAINLESS STEEL
PLATES, FORGINGS, BILLETS, SHEETS, BARS
Put your name on our list to receive the
G. O. CARLSON, INC.
WEEKLY STAINLESS STOCK SHEET
Even the largest stock of stainless plate in the country changes from week to week—so G. O. Carlson, Inc. gives you the actual stock on hand each week—mailed to you each Friday at no cost to you.
Put your name on the G. O. Carlson list today
G.O. CARLSON, INC.
Stainless Steels Exclusively
THORNDALE, PA.
FILL OUT AND SEND US THIS CONVENIENT FORM
G. O. CARLSON, Inc., Stainless Steels Exclusively
Thorndale, Pa.
Please put my name on your list to receive your weekly stock list of stainless steels.
NAME
TITLE
COMPANY
ADDRESS
ZONE
STATE
CITY

Personals

P. J. AUGUSTA is now chief chemist in charge of finishing department, Gries Reproducer Corp., Bronx, N. Y.

Formerly assistant metallurgist at American Brake Shoe Co., DONALD S. PARKER has accepted a position as metallurgist at the Naval Proving Ground, Dahlgren, Va.

SHEN LIH-MING is enrolled at Wayne University, Detroit, studying metallurgy.

R. G. HARDY is at present doing process engineering work at Howard Foundry, Chicago.

ALAN U. SEYBOLT has recently joined the research laboratory, General Electric Co., Schenectady, N. Y., where he is engaged in metallurgical research in the nucleonics section.

Having been temporarily associated with Ekstrand & Tholand as research engineer since his discharge from the Army, DORMAN G. FREARK is now at the College of the City of New York as a lecturer in shop processes.

JOSEPH URBANO is now president of Westbrook Industries, Inc., Newark, N. J., manufacturers of tools, dies and special machinery.

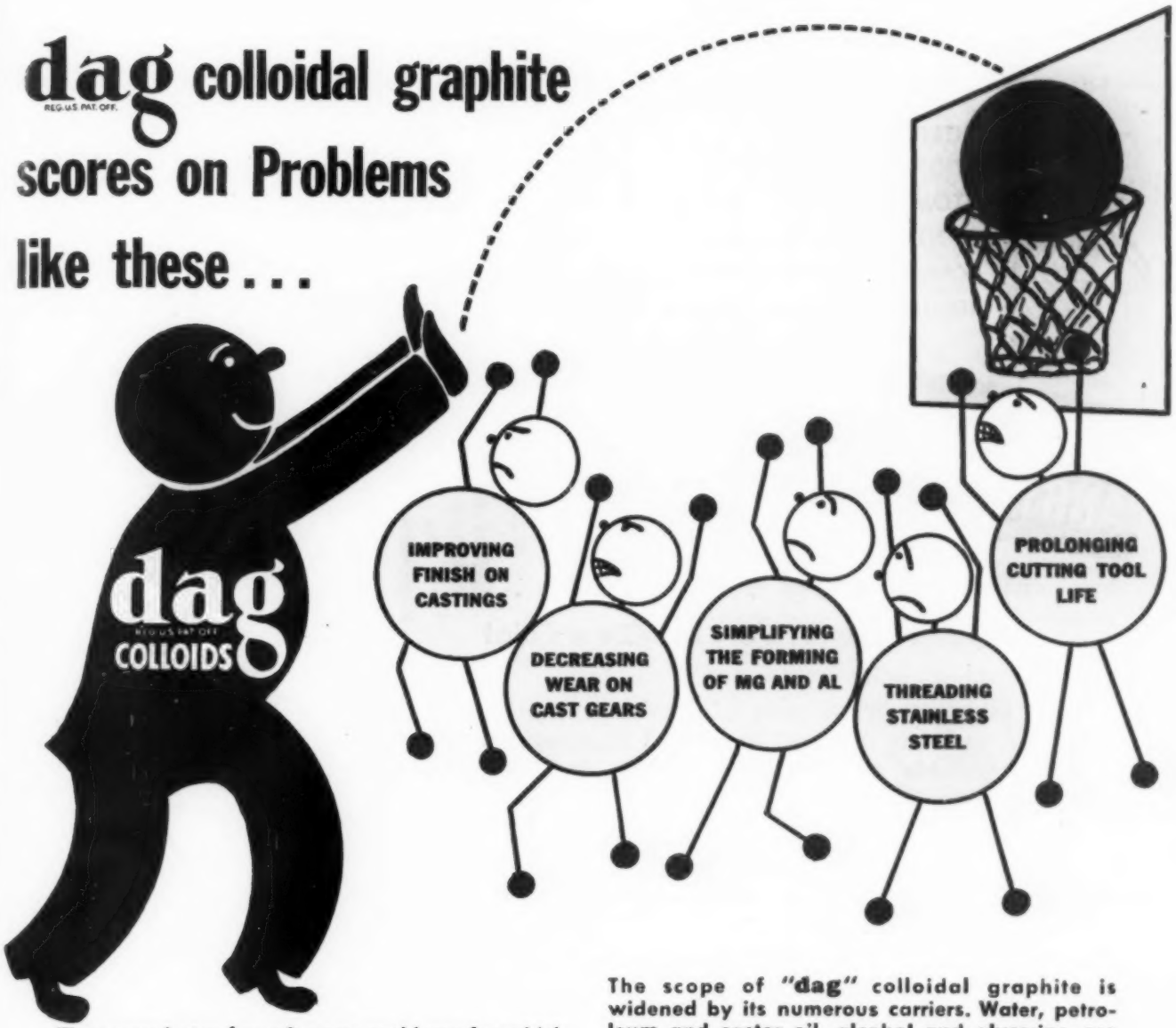
On completion of the requirements for his M.S. in metallurgical engineering at the University of Kentucky in Aug. 1947, CHESTER F. ROBARDS has joined the National Advisory Committee for Aeronautics in Cleveland.

KARL T. ASZT has resigned his position as assistant metallurgist at U. S. Metals Refining Co., Carteret, N. J., to study and act as demonstrator at the University of Toronto, Canada. He will also do research for the Ontario Research Commission which awarded him the scholarship.

After graduation from Marquette University in August, JAMES L. SCHMITT has accepted a position as junior engineer with the Peerless Pump Co. (division of Food Machinery Corp.) in Quincy, Ill.

ROBERT E. SHAFFER, formerly at Iowa State College, Ames, Iowa, has joined the staff of the school of engineering, University of Buffalo, as associate professor of engineering in charge of metallurgy.

dag colloidal graphite scores on Problems like these . . .



These are but a few of many problems for which "dag" colloidal graphite is often the only practical answer. Any problem requiring a slippery dry solid lubricant which conducts heat and electricity and resists extremes of temperature; which is truly colloidal in size and therefore capable of capillary penetration; which is chemically inert and anti-corrosive, opaque and gas-absorbent, is a problem for the "dag" team of properties to challenge.

The scope of "dag" colloidal graphite is widened by its numerous carriers. Water, petroleum and castor oil, alcohol and glycerine are some of the 18 available dispersions. Acheson technicians work constantly on new applications for the attack on specific industrial problems.

Your problem may be an old victim of "dag" colloidal graphite's versatility. Better see literature below. If yours is a new problem, better see Acheson engineers, and get the "dag" colloidal graphite team on your side.

ACHESON COLLOIDS CORPORATION, Port Huron, Michigan

This new literature on "dag" colloidal graphite is yours for the asking:

460 A data and reference booklet discussing "dag" colloidal graphite dispersions and their applications. 16 pages profusely illustrated.

421 Facts about "dag" colloidal graphite for ASSEMBLING AND RUNNING-IN ENGINES AND MACHINERY.

422 Facts about "dag" colloidal graphite as a PARTING COMPOUND.

423 Facts about "dag" colloidal graphite as a HIGH TEMPERATURE LUBRICANT.

431 Facts about "dag" colloidal graphite for IMPREGNATION AND SURFACE COATINGS.

432 Facts about "dag" colloidal graphite in the FIELD OF ELECTRONICS.

ACHESON COLLOIDS CORPORATION
PORT HURON, MICHIGAN, DEPT. L-10

Please send me, without obligation, a copy of each of the bulletins checked:

460 ☐ NAME_____
421 ☐ POSITION_____
422 ☐ FIRM_____
423 ☐ STREET_____
431 ☐ CITY_____ ZONE_____
432 ☐ STATE_____

for
NITRIDING STEELS
BRIGHT ANNEALING
ATOMIC WELDING AND BRAZING
CONTROLLED ATMOSPHERES
POWDER METALLURGY SINTERING ATMOSPHERE
REDUCTION OF METALLIC OXIDES

BARRETT STANDARD ANHYDROUS AMMONIA

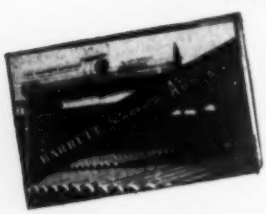
Minimum Purity 99.95% NH_3 . . .
Oxygen Free . . . Very Low Dew Point

BARRETT STANDARDS of consistent purity, uniform dryness, speedy deliveries and dependable service make Barrett Standard Anhydrous Ammonia your best source of NH_3 for metallurgical uses.

Because it is shipped as a concentrated liquid and can be dissociated into its component gases at points of use, Barrett Standard Anhydrous Ammonia is an economical source of nitrogen and hydrogen. When dissociated, each pound of Barrett Standard Anhydrous Ammonia produces approximately 11 cubic feet of nitrogen and 34 cubic feet of hydrogen.

Barrett Standard Anhydrous Ammonia is available in 50, 100 and 150-pound cylinders from conveniently located warehouses; or, for larger users, in 26-ton tank cars.

Modern metallurgy is finding more and more uses for Barrett Standard Anhydrous Ammonia. The advice and help of Barrett technical service men are yours for the asking.



This interesting and helpful booklet is packed with useful information on Anhydrous Ammonia. You can obtain a copy without charge or obligation, by requesting it from the address below.

THE BARRETT DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 RECTOR STREET, NEW YORK 6, N. Y.
ONE OF AMERICA'S GREAT BASIC BUSINESSES

Barrett

Alumina From Clay

IT IS WELL KNOWN that nearly all aluminum comes from bauxite ore, an impure aluminum hydrate. Impurities, especially silica, must be low, else much alumina is locked up and lost in the tailings ("red mud") in the Bayer process used for purification. During the war an additional operation of sintering this red mud with limestone and soda was able to recover 70% of this locked-up alumina.★ This in effect is recovering alumina from clay (hydrated alumina silicate), but since there is an unlimited amount of clay in the earth's crust, there is a continual incentive to study means of getting the metal out of it, which is in reality a low-grade ore of aluminum. In the last 75 years at least 60 such processes have been proposed. These processes can be divided in two groups — alkaline and acid. In the acid processes there has been the serious problem of corrosion of equipment.

At one period during the war, our shipments of bauxite — most of which came from Dutch Guiana — were all but stopped by submarines in the Caribbean, and an unusual amount of study was consequently given to other sources. The Kalunite process, installed in Utah to treat the mineral alunite, is in reality a sulphuric acid process, as is the process developed and operated by the Tennessee Valley Authority at Wilson Dam, Ala. A process using ammonium sulphate was also worked out by the Chemical Construction Co. in the Pacific Northwest. Several alkaline methods which were worked, at least in pilot plants, sintered the clay with lime or lime-soda, after which the aluminum salts were leached out with sodium carbonate solution or with water. Among such processes are those developed by the U. S. Bureau of Mines, Monolith Portland Cement Co., Ancor Corp., and by Aluminum Co. of America. The Anaconda Copper Mining Co. carried through the pilot-plant stage a process known as the Becco process, which began as a hydrochloric acid process but ended with the alkaline Bayer method.

Acid Process — The National Bureau of Standards turned attention to the problem in 1942, and between 1943 and *(Cont. on p. 850)*

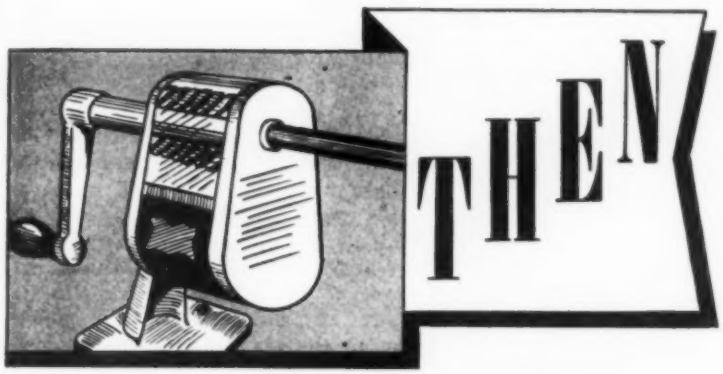
★See *Metal Progress*, Aug. 1942, p. 197, and May 1945, p. 918.

WHEN

YOU'RE SEEKING UNIFORMITY OF HEAT TRANSFER OVER LARGE SURFACES

AUTOMATIC—AND PRECISE—CONTROL OF COMBUSTION IS PARAMOUNT

THE USE OF PROTECTIVE ATMOSPHERES NECESSITATES INDIRECT FIRING



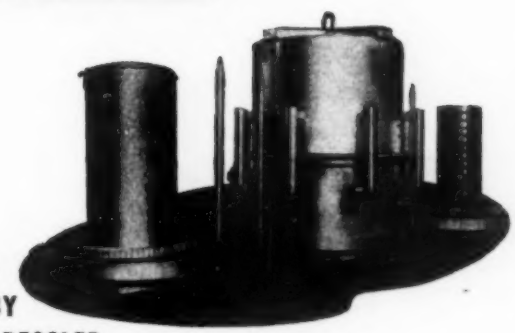
THEN

select a furnace with a KEMP firing system

The best furnace builders use the best firing systems—because they know that *better control over combustion characteristics and heat transfer patterns makes for better control over heat treating results.*

KEMP firing systems hold top spot in the quality parade because: (1) KEMP carburetors can maintain gas-air ratios more accurately, more automatically and more reliably than other fuel mixing methods, (2) KEMP systems can operate at higher burner pressures (even above 3 psi, if you wish) to provide wider control ranges and higher furnace capacities, and (3) KEMP burners can be engineered to the shape, zoning, intensity and mode of heat transfer desired.

Building furnaces is *not* KEMP's business — but building their carburetion-and-combustion systems *is* KEMP's business. Make sure your next furnace installation is KEMP-fired.



KEMP-FIRED ANNEALER BY SWINDELL-DRESSLER

Normal charge—25 tons of strip in 3 stacks. Used for bright annealing. Extreme specifications on product cover: (1) finish, (2) grain size, and (3) ability to be deep-drawn. Loading space under inner cover—6'6" diam. by 8' high. Heated by *vertical* KEMP radiators (radiant tubes)—plus a single *horizontal* one. All radiators are *recirculating* for higher efficiencies and better temperature uniformities.

KEMP OF BALTIMORE

PRECISION CARBURETION + ADAPTED COMBUSTION FOR INDUSTRY'S HEAT USING PROCESSES
ATMOSPHERE GENERATION & ADSORPTIVE DRYER SYSTEMS FOR PROCESS CONTROL AND PROTECTION

DEPT. K-E1 mp

The C. M. Kemp Mfg. Co.
405 E. Oliver St., Baltimore 2, Md.

Send me literature on your Series-S carburetors and firing systems.

NAME _____

POSITION _____

COMPANY _____

PLACE _____

Our furnaces are built by _____

DEMPSEY INDUSTRIAL FURNACES

Gas-Oil-Electric

BATCH • CONTINUOUS

ALL DESIGNS

ATMOSPHERIC BOX
IMMERSED ELECTRODE CAR BOTTOM
PUSHER REVERBERATORY POT
RADIENT TUBE
RECIRCULATING

ALL WORK

WIRE TREATING
FORGING AND BILLET HEATING
ANNEALING
NORMALIZING
CARBURIZING
HARDENING-DRAWING
MELTING
HOMOGENIZING
BRIGHT ANNEALING

There is a Dempsey engineer near you. Whether your needs be small or large, do it the DEMPSEY WAY.
Phone, wire or write—let us solve your heat treating problems.

DEPT. 3

FURNACES: Oil-Gas-Electric-"TAILORED" by DEMPSEY
Meet every Heat Treating Need

DEMPSEY FURNACES

DEMPSEY INDUSTRIAL FURNACE CORP.

Are You Missing

any information about

CERIUM*

"The Influence of Minor Elements on High Resistance of Standard Alloys" is the latest addition to the Cerium File Folder. It is available on request.

Is your name filed with us to receive new publications as issued?

*CERIUM STANDARD ALLOY

Containing 45-50% Cerium — Balance principally rare earth metals

Also available

CERIUM MASTER ALLOYS

CERIUM METALS CORPORATION

500 FIFTH AVENUE • NEW YORK 18, N. Y.

CERIUM

Alumina From Clay

(From p. 846) 1945 a pilot plant capable of producing satisfactory alumina by acid extraction was in almost continuous operation. (Significant discoveries were also made in the alkaline method.) Previous development of a hydrochloric acid process had failed because of the corrosion of metallic equipment. This problem, as well as the abrasive effect of precipitated aluminum chloride crystals, was overcome through the substitution of modern plastics, glass, and refractories.

Alumina can be dissolved out of all clays by treatment with hydrochloric acid in closed containers at 300° C. (575° F.), but the high pressures developed rendered this method of decomposition unsuitable for plant installations with the equipment available. However, it was found that roasting the clay at 700° C. (1300° F.) would break the chemical union between alumina and silica in the aluminum silicate molecule, and Al_2O_3 could be dissolved out with dilute hydrochloric acid at about 100° C. under atmospheric pressure, leaving insoluble silica behind.

In the Bureau of Standards' plant the acid filtrate is then evaporated to definite concentration and a little HCl gas precipitates aluminum as the hydrated chloride ($AlCl_3 \cdot 6H_2O$). The solid chloride is centrifuged, washed, and calcined to oxide while being rabbled down a multiple hearth furnace, muffled to recover the acid gas. The alumina obtained has an average purity of about 99.8%; the only significant impurities are 0.1% Cl, 0.04% FeO and 0.06% Si.

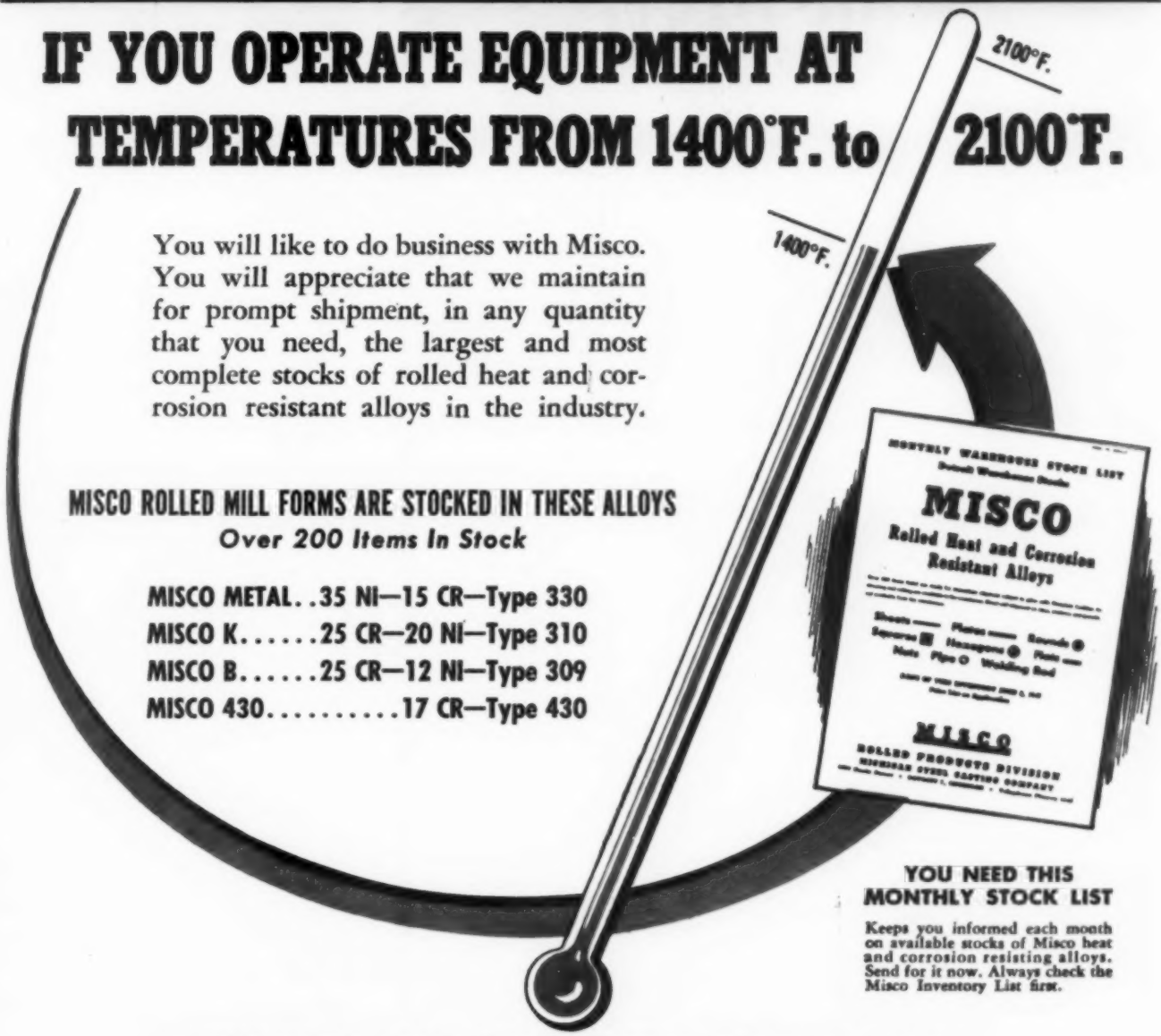
The price of producing alumina from reasonably good kaolin by the hydrochloric acid process is at present about twice that of producing it from imported bauxite by the conventional Bayer process. The two major cost items are fuel for heating and hydrochloric acid for make-up, of which the latter is the more important. Full recovery of waste heat by interchangers and acid gas by absorbers is impossible in operations on a pilot-plant scale.

Alkaline Processes — One of the fundamental principles of many of the alkaline processes is the conversion of the alumina in the ore to sodium aluminate, which is readily soluble in water. The iron is easily removed, since it is very insoluble in alkali, but *(Cont. on page 852)*

It's MISCO for
HEAT AND CORROSION RESISTING ALLOYS
IN ROLLED MILL FORMS

Sheets — Plates ▬ Rounds ● Squares ■ Hexagons ⬢ Flats ▬ Angles L
Channels U Sections Pipe ○ Nuts Welding Rod

IF YOU OPERATE EQUIPMENT AT TEMPERATURES FROM 1400°F. to 2100°F.



You will like to do business with Misco. You will appreciate that we maintain for prompt shipment, in any quantity that you need, the largest and most complete stocks of rolled heat and corrosion resistant alloys in the industry.

MISCO ROLLED MILL FORMS ARE STOCKED IN THESE ALLOYS
Over 200 Items In Stock

MISCO METAL..35 NI—15 CR—Type 330
MISCO K.....25 CR—20 NI—Type 310
MISCO B.....25 CR—12 NI—Type 309
MISCO 430.....17 CR—Type 430

YOU NEED THIS MONTHLY STOCK LIST

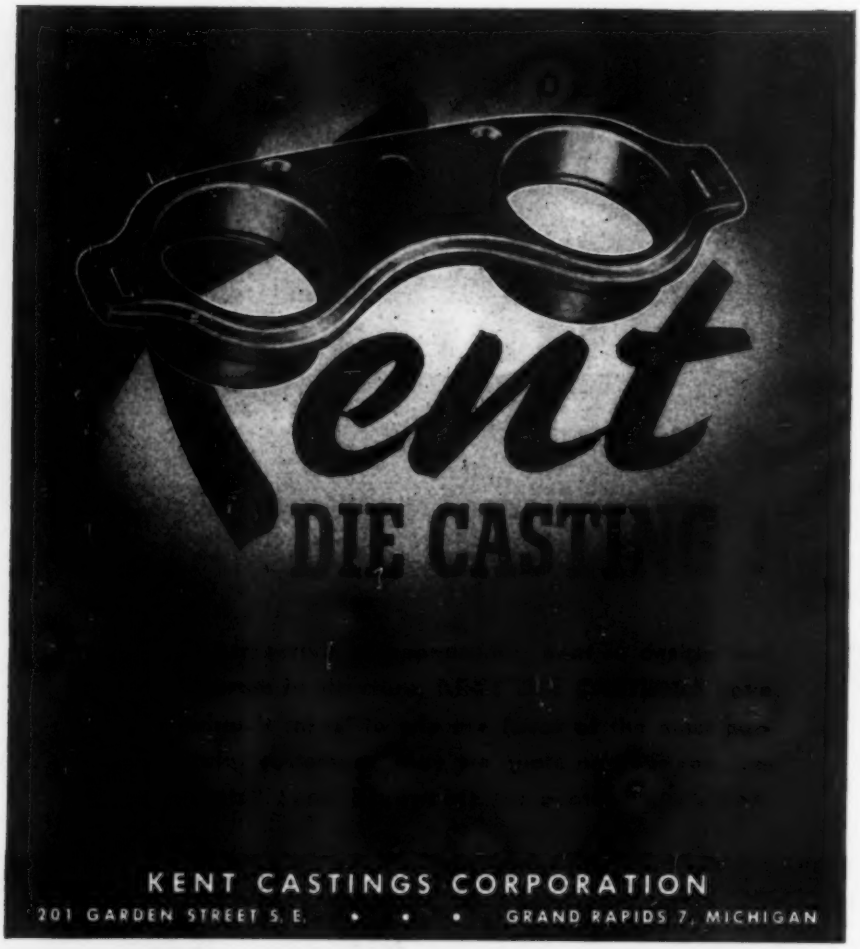
Keeps you informed each month on available stocks of Misco heat and corrosion resisting alloys. Send for it now. Always check the Misco Inventory List first.

ROLLED PRODUCTS DIVISION
Michigan Steel Casting Company

MISCO
Heat and Corrosion Resistant Alloys

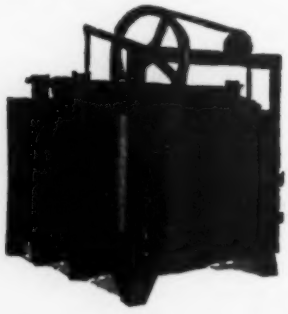
One of the World's Pioneer Producers and Distributors of Heat and Corrosion Resisting Alloys

1999 GUOIN STREET • DETROIT 7, MICHIGAN



JOHNSTON
HEAT TREATING
FURNACES

For heat treating, annealing and carburizing. Equipped with JOHNSTON "Reverse Blast" low pressure oil burners. Also available with JOHNSTON Tunnel Type gas burners.



Overfired and bottom vented with vent passages under tile floor. Uniform temperature and high efficiency. First grade fire brick or insulating refractory brick lining. Furnaces are manually or automatically controlled.

Write for Bulletin M-216

THE JOHNSTON LINE
JOHNSTON MANUFACTURING CO.
2825 EAST HENNEPIN AVE.
MINNEAPOLIS 13, MINN.
ENGINEERS & MANUFACTURERS OF INDUSTRIAL HEATING EQUIPMENT

Alumina From Clay

(From p. 850) considerable silica remains in solution. The problem is to rid the solution of the bulk of this soluble silica.

Analyses of the insoluble extraction residues showed that soda, alumina, and silica were present in simple, constant molar proportions, indicating that the residues might consist principally of a single compound. X-ray diffraction patterns strongly resembled those of the mineral sodalite, whose formula is $3NaO \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2NaCl$.

As a result of these observations, further extractions of the bauxites were made using sodium chloride in addition to the sodium hydroxide, and the silica content of the extracted solutions was immediately reduced to one tenth or less of the former value, since a compound of the sodalite type having a low solubility was formed during the extraction. This presented a method of reducing the silica in alkaline extraction solutions to a point at which alumina suitable for electrolytic reduction could be precipitated with carbon dioxide. Since only about 75% of the alumina in the impure domestic ores could be dissolved out with sodium hydroxide-sodium chloride solutions, attention was next directed to recovering this 25% of precipitated alumina and the soda carried down with it.

These investigations led to a more complete separation of silica from alumina in solutions obtained in the lime-sinter process, already in operation as an adjunct to the Bayer process. Ground siliceous aluminum ore was mixed with finely divided calcium carbonate in the proper proportions for a mixture of dicalcium silicate and calcium aluminate, sintered at 1400° C. (2550° F.), and cooled slowly to about 1200° C. (2200° F.). The dicalcium silicate played an important dual role in this procedure. First it held the silica in an unreactive form insoluble in the alkaline extracting solution. Second, it expanded on cooling with consequent reduction of the sintered mass to a powder — a process known as "dusting" — which rendered the alumina accessible to the leach without grinding.

From the available information, flow sheets for suggested commercial processes were prepared. About 95% of the alumina in the clay may be recovered, while losses of soda are small.

WHAT HAS MY PRODUCT IN COMMON WITH ALUMINUM BUILDINGS?

PLENTY, if you're looking for proof how a product, in a highly competitive market, can be given the advantages of aluminum at little or no increase in cost.

This new prefabricated farm and utility building is all-aluminum inside and out, never requires paint, is fire and vermin proof. The common assumption would be that its price is "out of this world" compared to steel. Actually, there's little or no difference in the final erected cost.

And that's where manufacturers are guilty of a common error in evaluating aluminum. They forget that pound for pound aluminum gives *three times* the working area of steel, brass or copper—often overlook the economies of handling and assembling this lightweight material, which, in the case of this building, cut erection costs in half. And, even more important, they fail to take into consideration that aluminum is available for immediate delivery at the lowest prices in history.

The true cost of aluminum doesn't stop with a price per pound quotation. Consideration of all the factors may disclose that you can't afford *not* to use this modern metal. The services of a Reynolds technician to aid you in this study are yours for the asking. Write Reynolds Metals Company, 2519 South Third Street, Louisville 1, Kentucky.

The price of aluminum has been reduced 30% since Reynolds became a primary producer in 1939.

REYNOLDS METALS

REYNOLDS
THE GREAT NEW SOURCE OF **ALUMINUM**

WARREN ANNOUNCES ATLANTIC SEABOARD FACILITIES AT NEWARK

Warren's LP-Gas marine terminal at Newark, N. J., now under construction, will receive its first cargo of propane via SS "Natalie O. Warren" early in December 1947.

This new tank ship and terminal brings to the Eastern Seaboard large additional supplies of LP-Gas, so badly needed for industrial, utility, and household uses.

Sales offices at 60 Park Place, Newark, N. J. Telephone Humbolt 5-1489.

"1922-Silver Anniversary Year-1947"

WARREN PETROLEUM CORPORATION
TULSA, OKLAHOMA
Detroit Mobile Houston

Scientific **STEEL TREATING**

Electronic Induction Hardening • Flame Hardening • Heat Treating • Bar Stock Treating and straightening (mill lengths and sizes) • Annealing • Stress Relieving • Normalizing • Pack, Gas or Liquid Carburizing • Nitriding • Speed Nitriding • Aerocasing • Chapmanizing • Cyaniding • Sand Blasting • Tensile and Bend Tests.

THE *Lakeside Steel Improvement Co*

5418 LAKESIDE AVE., CLEVELAND 14, OHIO HENDERSON 9100

Carbon Brick*

IN FEBRUARY 1947, there were 13 American blast furnaces operating with hearths built completely of carbon blocks or bricks, or lined with courses of shaped carbon. Twelve more complete carbon hearths were on order or in process of installation.

The following deductions have been reached from studies of the installed linings. The level of the horizontal hearth sections, when a pool of metal is to be provided, should be established somewhat lower than normal. The tendency at present is to raise the carbon crucible height; eventually, linings may be extended up to the mantle. Larger blocks are not only cheaper to install but also decrease the number of joints, which are always the weakest points in the lining. No breakouts through carbon lined blast furnaces have been reported in this country.

Carbon refractories were almost universally used in German blast furnaces. The carbon lining was installed up to the mantle and was either in the form of machined blocks or a rammed coke tar mix.

Based upon the European background and on American ferroalloy furnace experience, carbon blast furnace linings here have followed a rapid evolutionary pattern. In the article detailed records are given of the full crucible blast furnace linings of carbon bricks or blocks installed or on order in February 1946.

A double course of large blocks for vertical and horizontal hearth sections is desirable both for mechanical support and to cut down heat transfer. The blocks in the two side-wall courses are tapered sufficiently to set flush with each other, thus forming a wedged circle. Joints are staggered. The floor of the hearth consists of two courses of carbon blocks, each 22½ in. thick, set with staggered joints. Two-inch joints are allowed on all four vertical sides of the floor blocks. This width permits solid packing with carbon ramming mix by means of air rammers. This contrasts with German practice where the blocks were fitted together without ramming mix. The American practice is believed to give a better seal *(Cont. on p. 856)*

*Abstracted from "Progress Report on Carbon Linings for Blast Furnaces", by V. J. Nolan. *Blast Furnace and Steel Plant*, April 1947, p. 454 to 460.

What's the Story on Oxygen in Steel-Making Furnaces? No. 2 of a Series (No. 1 was a general review)

◀ The LINDE Jet Device inserted through door of the open-hearth furnace . . .

Oxygen at supersonic velocity is being injected through the LINDE Jet Device into the molten bath during decarburization

OXYGEN
Speeds Decarburization

THE GREATEST AMOUNT OF EXPERIMENTAL WORK on use of oxygen in the steel-making furnace has been directed toward shortening the refining period. Data on oxygen* use in more than 6,500 heats in 34 mills with which LINDE has co-operated have been recorded. Among these data are records of tests in which oxygen of various purities, compressed air, and even nitrogen, were injected into the molten bath.

All these tests produced rates of decarburization better than are obtained through normal ore practice. The effectiveness was greater, however, the higher the oxygen purity. With high-purity oxygen, rates of carbon reduction were increased two to four times over normal rates. Both the lance and Jet Device were used to introduce the oxygen.

Before final acceptance is assured, the equipment for injecting oxygen must be mechanized. The LINDE Jet Device, a water-cooled non-consumable tool, seems at present to offer the best opportunity for mechanization that will eliminate interference with charging procedures.

Much more extensive experience in individual shops must be gained before the optimum oxygen purity for use in each phase of steel-making can be determined.

*Supplied mostly as DRIOX high-purity liquid oxygen. Economics of low-purity gaseous oxygen will depend on purity, quantity, pressure required; size of storage facilities; and other demand characteristics.

Management and production executives are invited to write for the factual report which LINDE *has prepared on oxygen use in steel-making furnaces. Please address Room 308, 30 E. 42nd St., New York 17, N. Y.*

Linde
Trade-Mark

THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation
30 E. 42nd St., New York 17, N. Y. UCC Offices in Other Principal Cities
In Canada: DOMINION OXYGEN COMPANY, LIMITED, Toronto

The words "Linde" and "Driox" are registered trade-marks of The Linde Air Products Company.

Carbon Brick

(Cont. from p. 854) since the carbon ramming mix carbonizes under heat and virtually bonds the blocks into a monolithic section.

In the construction of the standard large block hearths, about 3 to 4 in. of coke breeze separates the outer course of the wall blocks from the shell. This serves several purposes, chief of which is a cushioning effect to absorb the expansion of the lining under heat. The heat and compression serve to drive off the volatiles and to bond the particles into a self-supporting wall. Although the carbon blocks are porous, the pores are so fine and the thickness of the blocks is so great that no penetration of metallic oxides or gases may be expected.

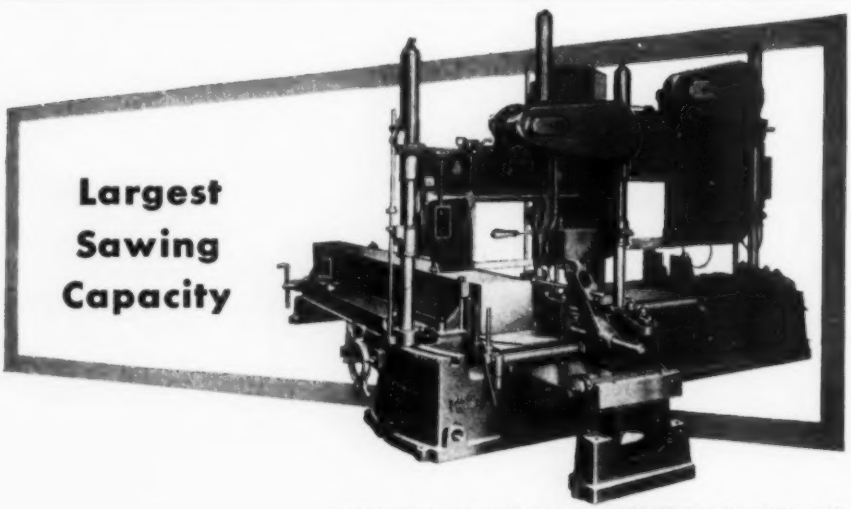
Ceramic brick courses on the side-walls between the carbon and the shell are seldom recommended. Fireclay brick may be laid over the carbon to protect the blocks during the blowing-in period, although no special precautions are needed if the furnace is afterward blown out and then blown in, as the slag, graphite and coke will protect the carbon blocks.

Crack Sensitivity*

THE COMBINED effect of sulphur and aluminum on porosity and crack sensitivity of five experimental heats of 4130 steel was investigated, in view of the good effect of high aluminum on these properties and the fact that sulphur contributes to the formation of pinholes. The circular bead test was used. The 300-lb. heats contained 0.012 to 0.047% sulphur and aluminum additions up to 6 lb. per ton.

As much as 6 lb. aluminum per ton did not increase porosity when the sulphur was 0.012% maximum. With 0.018% sulphur, the same aluminum addition caused a marked increase in pinholes, while abnormally high porosity was encountered with 4 lb. aluminum per ton when the sulphur was raised to 0.047%. Therefore, although both sulphur and aluminum contribute to surface pinhole porosity, the amount required to cause trouble is considerably higher than would normally be encountered. *(Continued on p. 858)*

*Abstracted from "Improving the Weldability of High Strength, Low Alloy Steels. Part III", by S. L. Hoyt, C. E. Sims and H. M. Banta, *Iron Age*, June 14, 1945, p. 74 to 80, 148.



.MARVEL No. 18—18" x 18" .MARVEL No. 24—24" x 24"

Designed and developed to bring true accuracy and economy to sawing big work up to 24" x 24". In hundreds of metal working plants from coast to coast, these giant saws have proven themselves to be the best cut-off equipment for the biggest and toughest steels. There are nine other types of MARVEL saws to meet every sawing need. Write for our catalog and give us an outline of your work. We will recommend the right MARVEL saw for your work.

Metal Cutting MARVEL SAWS
Better Machines—Better Blades

ARMSTRONG-BLUM MFG. CO.
"The Hack Saw People"
5700 Bloomingdale Ave. Chicago 39, U. S. A.

NO SCRATCHES . . .
LONGER HONE LIFE
with SUPERKOOL *

. . . reports
D. W. DEACON
D. A. Stuart Oil Co.,
Representative

This customer is honing cold drawn steel tubing on a Barnesdrill vertical No. 307 honing machine with a micromatic head. A 120-M Bay State stone removes 30 to 35 thousandths on the I. D. With Stuart's SUPERKOOL* Base mixed 4 to 1 kerosene no tool marks are in evidence, stone life is increased considerably, the finish is excellent and the customer praises SUPERKOOL No. 41* highly.

Douglas M. Deacon

* SUPERKOOL

. . . Stuart's Superkool is a concentrated base cutting oil with high anti-weld capacity and low frictional characteristics. Its light color affords clear visibility on operations where close gaging or constant inspection is necessary. Superkool is chemically stable, sterile, and has no objectionable odor. These are only a few of the reasons why it has been a standard in hundreds of plants for over twenty-five years.

Ask to have a Stuart Service Engineer discuss your cutting fluid requirements. SUPERKOOL Booklet available on request.

STUART *service goes with every barrel*
WRITE FOR DETAILS

D. A. Stuart Oil Co.
2743 SOUTH TROY ST., CHICAGO 23, ILL.

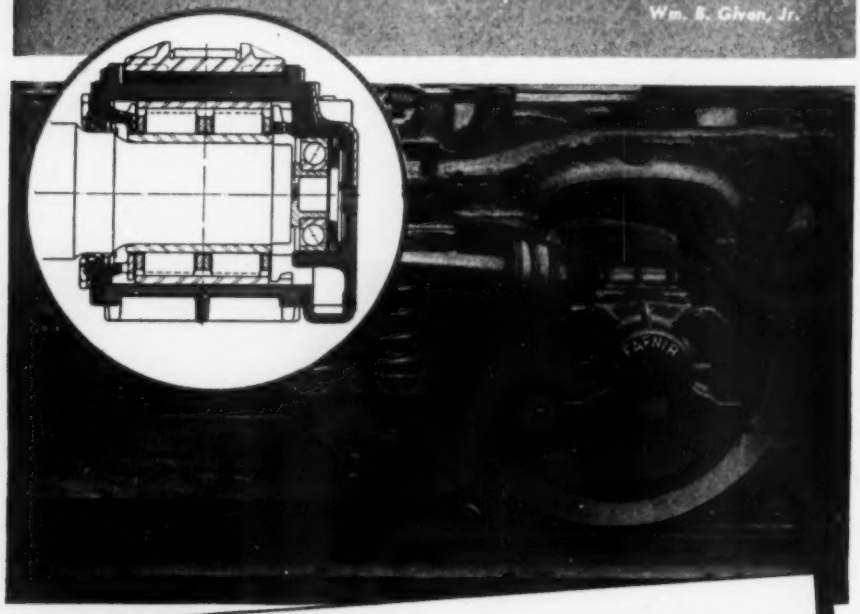
I'm *Doc Tillity*, one of Federated's friendly service men. Me and the other Federated service boys have worked with metals for quite a while now and . . . we know our stuff. What's more, we're ready to prove it to you any time you run into a metal problem, big or little.

Federated is a right large outfit— first in the whole non-ferrous field— and they're anxious to have us service men roll up our sleeves and help you out whenever you ask.

Remember, boys, for service . . . for anything in the non-ferrous metals line, call Federated first. Our offices are all over the country.

I'll be seeing you and talking to you again pretty soon. So long for now.

"Not only to serve today, but to anticipate tomorrow"
Wm. B. Given, Jr.



MEEHANITE® CASTINGS
as made by BRAKE SHOE

Two-in-one protection for a two-in-one bearing assembly

In the ingenious construction of Fafnir Railway Bearings, two separate bearings are combined in one assembly. They are a cylindrical roller bearing for radial loads and an independently-acting ball bearing for end thrust. To safeguard this two-in-one assembly, The Fafnir Bearing Company of New Britain, Conn. use castings of Meehanite *made by Brake Shoe* for a cover, for a housing and for a retainer on certain types of journal assemblies.

The selection of these castings provides two-in-one protection. In the first place, the Meehanite metal assures the high strength and vibration dampening that the high speed mainline operation requires, without sacrificing ready machinability. In the second place, the extensive experience of American Brake Shoe Company provides a knowledge of foundry techniques added to the services of consulting metallurgists and engineers. Thus the right metal and the right manufacturing methods assure castings that stand up in severe service.

Brake Shoe's metallurgical department includes an experimental foundry completely equipped for pilot plant work. Brake Shoe maintains foundries at Mahwah, N. J., Melrose Park, Ill., and Baltimore, Md. with facilities for producing widely used types of castings (light or heavy weight, green or dry sand or all core assemblies) including intricate and special types. Write us about your castings needs. We'll tell you promptly what we can do to help you.

Brake Shoe

BRAKE SHOE AND CASTINGS DIVISION
230 PARK AVENUE, NEW YORK 17, N. Y.

B478

Crack Sensitivity

(From p. 856) The decrease in crack sensitivity with increasing sulphur was more pronounced in the higher aluminum heats.

The effect of postheating on crack sensitivity and hardness was determined by the study of a limited number of photomicrographs. The postheating temperatures ranged from room temperature to 1000° F.; intervals from 1 sec. to 24 hr. Preheating was regarded only as a means of starting the postheating at the desired value; it apparently had no other influence on the results. The hardness-time-temperature survey showed a region of minimum hardness for times over 10 min. at 800 to 1050° F. This region corresponds to the portion of the S-curve where the transformation to bainite occurs most rapidly. High hardness at 900 to 1100° F. with times under 1 min. agrees with the slow rate of transformation indicated by the S-curve.

A plot of crack sensitivity against effective postheating temperature also indicated that greatest improvement coincided with the bainite region. However, the hardening effect of ferrite precipitation between 1200 and 1300° F. in the time interval of 20 to 60 sec. was not shown in the "apparent crack sensitivity index". It was found that the postheating conditions which yielded the most satisfactory results corresponded to the conditions in the S-curve most favorable to the formation of bainite.

The correlation between hardness and cracking is definitely limited. Below 460 Vickers, the crack sensitivity is uniformly low so all welds would be completely free from cracks. Any hardness above 575 Vickers can be accepted as proof that extensive cracking will be encountered while the apparent crack sensitivity index varies widely in the intermediate range so that hardness alone cannot be used to predict the degree of cracking.

Although it is not always possible to duplicate welding procedures, the crack sensitivity of a steel can be evaluated as a percentage of the crack sensitivity of a standard steel. This evaluation may be made independent of the test conditions, provided these conditions are constant within each pair of tests and provided they do not fall in a range where either the material fails to crack or where either steel cracks by the operation of some new process.